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I. THE MUSIC OF SPEECH.

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Of all the gifts of God to man, the most godlike, that of rational speech, is universally the most neglected. The neglect is without extenuation, and particularly in the matter of our native tongue. A sonorous and yet easily modulated language, English offers many advantages to the elocutionist. The language as a language has been studied most thoroughly. So much might be said of the languages of all civilised countries. But can we go a step further and say that speech has been so far studied that anyone of moderate attainment in science can explain how sentiment, logical continuity, or logical conclusion are expressed in elliptical sentences or phrases,—can tell how a "yes" may imply negation or a "no" affirmation? Certainly not. Yet we send our sons to school or college to imbibe what is generally understood as the "*je ne sais quoi*" of intonation without thought as to whether or no that peculiar and admired style is imparted upon principle or only by imitation. Need it be said how often imitation is too late discovered to have been the routine pursued. And what are the consequences? The boy completing his education enters a profession or the counting-house, and in addition to his own mannerism falls into those most prominent among his fellows. Thus he obtains a peculiar intonation, pleasing or the reverse—thus is there one set tone pervading certain cliques of society, too hackneyed a subject for re-consideration here.

We Englishmen, or those of us who cry so loudly for "progress," should be proud that the discovery that speech has a peculiar music of its own is due to a member of an English-speaking nation. Dr. James Rush, of Philadelphia, in his "Philosophy of the Human Voice," has shown that the sentiment and the logic of our speech have a distinct mode of expression apart from the subject-matter—has, in fact, discovered the true meaning of "correct intonation." His views and researches have not been published to-day; in America the work has reached the sixth edition; here it is comparatively unknown. In the following pages, then, will be attempted an epitome of Dr. Rush's investigations, showing that a standard of correct elocution is no longer a matter of arbitrary taste, but has passed into the defined and law-ruled realms of science.

The constituents of the human voice may be referred to the five following modes :—

Quality,
Force,
Time,
Abruptness,
Pitch.

The quality of a voice is sufficiently distinguished by the metaphorical terms—rough, smooth, harsh, full, thin, musical. This mode does not require any elucidation. "Even in simple conversation," says M. Garcia, "if the intention be to represent anything extensive, hollow, or slender, the voice produces, by a moulding movement, sounds of a corresponding descriptive character."

There is a peculiar quality pertaining to the voice of an actor or orator of long practice, ordinarily described as "roundness of tone," the *ore rotundo* of Horace. This orotund quality may be acquired without that long and wearying toil to which the professional speaker must submit, as, indeed, may be acquired any vocal mode by diligent analysis. First we notice in this quality of voice a resonance similar to that possessed by a musical instrument, the tone of which has become mellow by age. Again we notice that in coughing a certain fullness of tone can be sometimes recognised in the short percussive vocalities. The resonance of the musical instrument arises from a definite relation of the vibrating body of air within the instrument to the number of vibrations made by the reed or string per second. In speaking into a vase there are some notes of the voice which find, as it were, an answer, and are produced with greater sonority. When in coughing we contract portions of the pharynx, this resonant cavity of the mouth then contains a body of air capable of being set in vibration by the tone uttered; the result is a peculiar fullness or breadth amounting occasionally to hoarseness. The vocality of the cough has the duration only of the passing breath; keeping the organs in their assumed position, and prolonging the breath, we obtain the desired orotund quality of voice. We have artificially placed our vocal organs in the position assumed by those of an experienced speaker. We have, too, found that there are two distinct forms of respiration—the one continuous, in which the orotund is first produced; in the other the breath issues in interrupted jets. In continuous breaths we sigh, groan, and sneeze. The interrupted jets of breath are employed in speech, in laughing and crying. Having acquired a continuous orotund vocality—a child first cries in long wails—the student must learn to interrupt this continuity and to speak in the orotund voice, soon as easy to him as his colloquial speech. Thus a thoughtful investigation gives immediately that which in long years even assiduous practice may fail to accomplish by mere imitation.

The terms usually employed to denote variation in degrees of force are also self-descriptive.

Mr. Millard,* who with Professor Bell, of University College (Lond.), has devoted considerable attention to the scientific study of vocality, very clearly subdivides the time or duration of the voice into—

1. Quantity or sound heard;
2. Rate;
3. Pause or rest.

"By quantity is meant the length of sounds heard separately; by rate the pace of sounds heard in succession; and by pause the measure of silence or rest." Mr. Steele, in his "Prosodia Rationalis" (1779), gives examples of an application of the symbols of music to his idea of the time of discourse. But these are constituents of speech each worthy a separate volume to consider and exemplify.

Exception might, perhaps, be taken as to the correctness of giving a specific division to abruptness; but Dr. Rush thinks this a mode of the voice quite distinct from that of force. It is perhaps a delicate point. Abruptness is analogous to the *staccato* of the musician. We come now to the most subtle and the least understood constituent of speech, variation in pitch or the variations of the voice between gravity and acuteness. And here we must assume that the reader has a slight acquaintance with the intervals of the notes of music. "As music and speech," says Dr. Rush, "when regarded under the mode of pitch, are subdivisions of the general science of tunable sound, the reader will perceive the necessity of designating and explaining those terms which belong alike to both, or are restrictively appropriated to each." The different degrees of pitch in music are denoted by what is termed the *scale*, the relation of which to speech may be thus illustrated. When the bow is drawn across the string of a violin, and the finger at the same time gradually moved, with continued pressure on the string, from its lowest attachment to any distance upwards, a *mewing* sound, if it may be so termed, is heard. This mewing is caused by the gradual change from gravity to acuteness, through the gradual shortening of the string: and as it thus rises by a succession of uninterrupted momentary changes, each continuous or concreted, as it were, in its increments of time and motion, let it be called a *concrete* sound. This movement of pitch on the violin is termed a *slide*.

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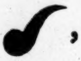
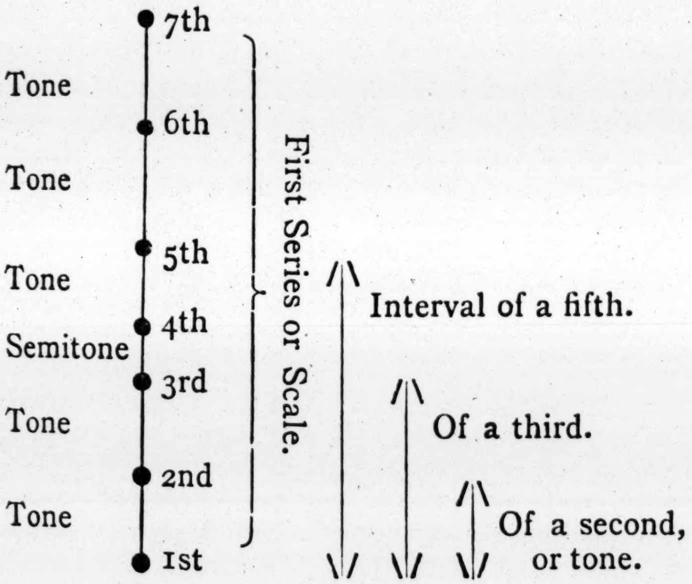
* A Grammar of Elocution. Longmans.

The reader may himself exemplify this concrete sound by uttering the single syllable *aye*, as if he were asking a question with the expression of earnest surprise, yet rather deliberately, beginning at the lowest and ending at the highest limit of his voice. The gradual rising-movement in this case is concrete; yet as the voice, and any other tunable sound may be continued in one interrupted movement upon the *same line* of pitch, without rising or falling, it is proper to remark that the term concrete is in this paper applied only to an uninterrupted movement in a *rising* and in a *falling* direction. Now, the sounds of what is called the *scale* in music do *not* rise by connected or concrete movements; but are made by drawing the bow only while the finger is held stationary at certain successive places on the string, thus showing an interruption of the continuous upward slide. These places are seven in number; their distances from each other being determined by a natural law, and rendered precisely measurable by a scientific rule for subdividing the string, which we need not consider here. Other sounds, still ascending on the string above these seven, may be made by a similar interrupted progression. But since the second series of seven sounds, though of higher pitch, yet adjusted by the same rule, do each to each in order so nearly accord with the first seven that they may be considered as a kind of repetition of them, and as the same is true of all the series of seven that may be formed between the lowest and the highest limit of sound, the whole extent of variation in acuteness and gravity is regarded as consisting of the simple scale of seven sounds, repeated in different series or ranges of pitch. Thus, while we take the line in the annexed diagram to represent the concrete progress of the voice, the positions of the notes, represented by the black discs, will distinguish the discrete progress in singing or on the pianoforte. While the progress between two notes of music may be represented by two discs, the progress of the voice in speaking may be well represented by or more elegantly thus— , denoting the full, rotund opening and the delicate attenuation of the inflection. This explanation of the manner of concrete and discrete progressions in an upward direction is to be understood of the downward course, under a reverse movement of the gradual slide on



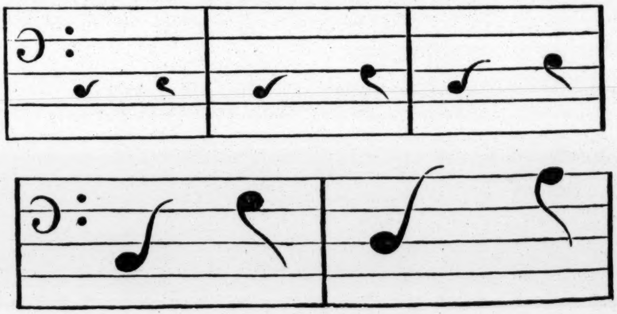
the string. The variations of pitch on most musical instruments are discrete. The violin and its varieties derive much of their expressive power from being susceptible of the concrete movement, this movement being one of the great sources of expression in the human voice. Having thus pointed out the distinction between the discrete movements of the voice in singing and the concreted movement, also termed the slide or inflection in speaking, we may at once proceed to analyse these movements of the speaking voice, and to ascertain their corresponding mental conditions. We shall see that each mental state—enquiry, surprise, assertion, command, remonstrance, threatening, scorn, and sarcasm—has a corresponding mode of inflection, these modes collectively forming a natural language intuitive alike to all. It is the perversion or disconnection of the tone of voice from its corresponding mental condition that makes ordinary reading aloud "like sweet bells jangled, out of tune and harsh." "A *natural* expressiveness," says Professor Bell, "may and should be given even to the A B C."

Inflections are either—

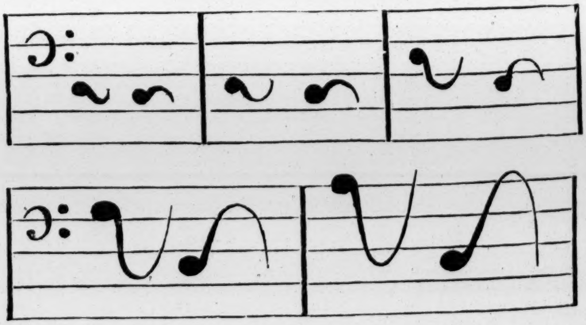
1. Simple; or,
2. Compound,

both forms being either rising or falling. A simple inflection consists of a single slide of the voice in either an upward or downward direction; thus, / or \. The compound inflection is obtained by uniting two or more simple inflections; thus, /\ or \/. When the last interval is an upward inflection the compounded inflection is said to be rising; and when the reverse is the case the compound inflection is said to fall. The expressiveness is in all cases limited by the interval through which the voice passes.

Simple Inflections.



Compound Inflections.



It is clear that the limbs or constituents of a compound inflection may be equal or unequal. Of the multiform permutations of the several inflections we cannot here give an account, nor is it necessary; for let once the principle be grasped, and the deduction of specific rules is an easy matter. Mr. Millard says:—"The fundamental law of inflection, under which, indeed, nearly all the rules written by elocutionists may be included, is as follows:—The rising inflection is indicative of doubt and incompleteness of expression; the falling, of certainty and completeness of expression; the *length* of the slide varying in accordance with the speaker's intensity.

Thus, if I put the question, "Do your know your lesson?" to a boy confident in his knowledge, he would give his affirmative with one of the falling intervals:

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Yes.

And here the verbal and vocal sign would justly and expressively coincide. If, on the other hand, he were doubtful, though affirming by the *word*, the rising inflection, which by the natural law he would employ, would overrule the verbal sign and betray his doubtful state of mind:

/
Yes.

From this general law all specific rules for the management of the voice may be deduced. Thus, with regard to questions which, in their purely logical form apart from sentimentality, may be considered as conveying neither affirmation nor denial, the meaning being evolved from the answer, the inflection is naturally a rising one, the lowest limit of the interval being a major third. This moderate degree of inflection is, however, rarely to be met with in ordinary conversation, sentiment or a false habit of intonation extending the interval employed to a fifth or even more. And here arises one of the causes of failure of an untrained speaker on a public platform—he having at most only an octave and a third or fifth at his command, and seldom even this, in using the extended intervals to convey ordinary meaning, leaves literally no room for effect; and in rendering impassioned passages requiring relatively longer inflections, degenerates into a scream or a monotonous growl. Perhaps the day may not be far distant when from all professorial chairs of elocution students shall be taught to restrict their mere assertion within proper vocal limits, leaving the remaining notes of their voices to the cause of expression.

Questions are sometimes assertions in disguise, and may be regarded as, or even more than, assertions; for instance, "*Who said so?*" may be fully rendered (with the downward inflection), "*Tell me who said so.* Finally, the belief implied in a question may be overruled by the passion with which it is asked. Thus, where Byron says, "*Shall he expire, and* *unavenged?*" the belief of the speaker is accompanied with anger, indignation, and other states of mental excitement.

Imperatives will of course take a downward direction, as also will exclamations. In the latter case how often do we hear on the amateur platform the exclamation of Macbeth, *What hands are here!*" rendered with the rising inflection as a question. We cannot here dwell upon the numerous rhetorical forms of speech—a little thought on the reader's part will soon enable him to class them as being subject to a continuative rising or a decisive falling inflection, bearing in mind the direction of one of our oldest poets—

> "The wise Plato sayth, as ye now rede,
> The word must need accorden with the dede;
> If men shall tellen proprely a thing,
> The word must cosin be to the werking."

The simple musical intervals and their correlated mental states may be recounted as follows:—

The Tone.—This interval should be considered the interval of unimpassioned speech; for, as we judge of all musical intervals relatively, it matters little what we adopt as a unit. However, from the peculiar nature of the musical scale, the tone only is the unit that can be adopted in rational speech. If this be done the rising tone will be indicative of continuity, and the falling tone of the approaching completion of the sense. Finally, three successive falling tones indicate the completion of a merely assertive sentence.

The Third.—Two tones, or a third, is the musical interval correlated to that state of mind which may be termed moderately assertive or appellatory. As has been said, the interval is naturally employed (either in three successive syllabic tones or otherwise) in the completion of an assertion.

The Fifth.—Falling; this interval denotes command, exceeding confidence, wilfulness, or petulance; rising, it appeals in surprise or passion. While the *octave* is expressive of still more passionate feelings.

The reader may exemplify to himself these intervals by the utterance of the following formulated phrases:—

Rising:

3rd.	5th.
Is it gone?	Can it be gone?

Falling:

3rd.	5th.
It is gone.	It must be gone!

There is yet another interval, *the semitone*, which, as can be most easily exemplified by repairing to the pianoforte, is expressed of plaintiveness or melancholy. "Pity the sorrows of a poor old man" is a sentence that to be read with effect should be read entirely in semitones.

We must now pass to the consideration of the complex or compound inflections correlated to complex states of mind. Perhaps there is no better proof of the truth to nature of the system of musical inflection (if we can call that a system which is really natural) than is afforded by an analysis of these complex intervals. They will be found to consist of united simple inflections, being thus antithetic in their nature. A complex interval is employed only in reference to some matter previously understood. For formulated expressions conveying an idea of the movements of the voice the student of speech is indebted to Professor Bell, whose endeavours to render speech graphically were long ago recognised by the Society of Arts. He exemplifies the compound tones as follows:—

Rising:

3rd.	5th, or Octave.
(Remonstrance)	(Threatening)
Not—	Certainly not—

Falling:

3rd.	5th, or Octave.
(Scorn)	(Sarcasm)
But—	Or rather—

the dash being supplied by the accented word. Let the reader make a few trials with the word "so" or "thus;" his ear will soon be enabled to measure the intervals.

This measurement of the intervals is the great difficulty of the system; a certain but essentially slight musical training is necessary to enable the student to cultivate his own voice or judge of the intonation of others; yet the difficulty is so small, and the consequent rewards so great, that one would not imagine it to impede the progress of the analytic study of the voice. This would, however, appear to be the case, since teachers of elocution delight more in the enunciation of arbitrary rules than in the enquiry how Nature provides for the utterance of the thoughts of man.

Science has advanced so far that it may be stated almost generally that that which is evident to one sense may be also made evident to another. In Leon Scott's phonautograph, and in König's manometric flames we have two beautiful illustrations, where speech, as sound evident to the ear alone, is stopped in its vibratory path and made to record itself to the eye.

These instruments are now too well known to need description here; it may perhaps suffice to say that the author has with these instruments analysed visibly many of the complex modulations of speech, reducing them to the principles first evolved by the fertile brain of Dr. Rush.

Of the remaining constituents of expressive speech, such as emphasis, full or median stress, &c., it is here needless to speak—they are sufficiently well known to students of music in their occurrence in the singing voice. But there is an almost distinct character—it cannot be termed a constituent—of beautiful speech upon which we must dwell. It is *rhythm*. And again the English reader meets with assistance from the character of his language. With the French language the case is different. It has, indeed, a perceptible variation in the force of its accents, and in the duration of its quantities; but not sufficiently marked, nor of such a systematic character as to make an available prosodial meter. The French epic and dramatic lines, for they cannot be called prosodial measures, properly consist each of twelve syllables, though they have sometimes ten or eleven. Among them is occasionally found a succession of accent and quantity resembling the various structures of English verse. There is an example of anapæstic measure in the first canto and second line of Voltaire's *Henriade*, "*Et par droit de conquête et par droit de naissance.*"

Allowing for the manner of the French in prolonging their syllables many like correspondences to the usual English measures may be gathered from what they call their heroic rhyme. But all such cases are accidental in French versification, and do not accord with the general character of its irregular succession—a succession shocking to the English ear, and utterly without a flowing rhythmus either as poetry or prose. Speech would not be convenient for the interchange of thought and passion if *every* syllable of every word were successively accented. For by this uniform accentuation it would want that vocal light and shade, and that pronounced relief required for a distinct picture of ideas —words, and consequently ideas, would not be easily distinguished from each other, and speech would be inconveniently slow. Whether this slowness would result from the hiatus in passing from one syallable to another, each with a full radical stress upon it, we need not here inquire. Thus, to the alternation of strong and weak accent, with the variations of long and short quantity, is ascribable much of the power and beauty of speech. This being the character of the accentual function, Mr. Steele, by an original view of the relations between accent, quantity, and pause, made a division of the line of speech, analogous to that of the bars of musical notation. These may be called accentual sections. We will attempt to explain part of the system of Mr. Steele by the following sentence, using italics in place of his symbol for the accented syllable, and numbering the sections merely for reference :—

1 2 3 4 5 6
⌉ In the | *sec*—ond | *cent*—u-ry | ⌉ of the | *christ*—ian | *e*—ra |
7 8 9 10 11 12
⌉ the | *em*—pire of | *Rome* | ⌉ compre- | *hend*—ed the | *fair*—est |
13 14 15 16 17 18
part of the | *earth* ⌉ | ⌉ and the | *most* ⌉ | *civ*—i-lised | *por*—tion |
19 20
⌉ of man | *kind.* |

Mr. Steele first assumes the time of the several bars to be equal, like that of the bars in music, the term bar meaning not the vertical lines but the space between them. He next subdivides a sentence into bars, each of equal time, that time consisting either altogether of verbal sound or of a verbal sound and of a silent time or pause. Supposing, then, a bar or accentual section to contain in its verbal time, one, and never more than one, accented syllable, or heavy *Poize*, as he calls it, and one or more unaccented, which he calls the light *Poize;* the beginning of the bar is always occupied by the heavy accent, and the end by the light, or in their absence by a respectively equivalent silent time or pause (⌉). In the first bar of the above example there is no heavy accent, for the sentence begins with two light syllables, but its time is indicated by the symbol of a silent pause; while the two light are set at the end of the accentual section. The word *second*, in the next bar, has a heavy syllable followed by a light one, and thus makes a full and audible time. In the third bar, the word *century* has a heavy, followed by two light syllables. The fourth has the same time in syllable and pause as the first. And so on. It is worthy of remark, that if this sentence is read without its linear divisions, the voice of a good reader is disposed to make its pauses in those very places, and of that duration, visibly indicated by the vertical lines placed before the accented syllable and by the symbols of pauses both in the light and heavy part of the bar. It will, perhaps, be asked here—What is the meaning of these divisions? And what useful purpose they serve in instruction? All works on elocution, before the time of Mr. Steele, recommended the accurate accentuation of words, and a strict attention to their separation at the proper places for pausing. And although Mr. Sheridan has given particular cases of notation for rhetorical emphasis and for pause, he has proposed no broad rule to direct a pupil on these points, as Mr. Steele has done, in his simple divisions by bars placed before the heavy accent. The importance of the subject in our early schools may be learned from the manner in which children begin to read; for their hesitating utterance, and their close attention to the single word, lead them to lay an equal stress on every syllable, or at least on every word. This habit continues a long time after the eye has acquired a facility in following up discourse, and in some cases infects pronunciation throughout subsequent life; as it is not till the tongue goes tripping, or rather halting, with its firm and tender step on words, that the ear becomes sensible of the use and beauty of accent.

Dionysius, of Halicarnasus, in a summary of the constituents of an elegant elocution, describes rhythmus, as supporting or "sustaining the voice;" and it must be admitted that a well-marked arrangement of the varying stress and quantity of syllables does sustain the voice, by keeping it from that careless staggering of speech, that running of words against each other, which by crossing and arresting the easy step of language, confuses and thwarts the expectation of both the ear and the mind. "From the pen of a person of fine rhythmic perception," continues Dr. Rush, "even a letter of business, with its enumeration of particulars, may flow with graceful variety, and terminate with decisive satisfaction to the ear; for the Greek idea of rhythmus sustaining the voice in discourse, applies not more to maintaining a rhetorical dignity, than to preserving common language from a loose and unmeasured rudeness."

Of the power of rhythm to confer freedom of speech none are perhaps more aware than those who undertake to cure stammering and stuttering, it being the corner-stone of their systems: the defined beat of a well-marked line can be made to coincide with the pulsation of the stutterer. When talking to a stutterer one will find occasionally very difficult combinations of letters uttered with perfect freedom, simply because the rhythm has not been interrupted. Very few who stutter in speech do so when singing.

The further details of the subject of rhythmus must be left to the rhetorician. We have said enough to show that, in the words of the great Vandenhoff, "The human voice is to be considered as a musical instrument—an organ constructed by the hand of the Great Master of all harmony. It has its bellows, its pipes, its mouth-piece; and when we know the 'stops,' it will discourse most eloquent music. It has its gamuts, or scales of ascent or descent; it has its keys or pitch, its tones, its semi-tones, its bass, its tenor, its alto, its melody, its cadence. It can speak as gently as the lute—'like the soft south upon a bed of violets'—or as shrilly as the trumpet; it can tune 'the silver sweet note of love,' and the iron throat of war. . . . The art that wins this music is elocution."

II. A FEW THOUGHTS ON THE DECIMAL SYSTEM.

THE decimal system of notation is the system in vogue not only in England but also in most, if not in all, countries. The fact that all nations count by tens would seem to point to some one and the same cause influencing all nations alike. This cause is probably found in the fact that man has ten fingers. It is very common to indicate any number by holding up the same number of fingers. This is observed in our own country, and many a man in a strange land, with the language of which he was not familiar, has noticed the same method of explaining what number has been mentioned.

Now man having *only* ten fingers, when any larger number is to be denoted by this method all the fingers are held up, the hand is then closed, then all the fingers are again held up, and so on until the requisite number of tens has thus been indicated, when as many fingers are displayed as may be required to denote the units.

Thus the simple fact that man has ten fingers seems to have settled what is really a question of some importance, viz., the scale of notation to be employed by the whole human race. It seems questionable whether the decimal system is really the best; indeed, many who are considered the highest authorities on the subject seem to incline in favour of the duodecimal scale, or counting by twelves. One argument in favour of this scale over the decimal is that the radix 12 is exactly measured by the numbers 2, 3, 4, and 6, besides itself and unity, whereas 10 is only thus measured by 2 and 5.

It does not, however, seem at all probable that we shall change our present system of notation, at all events for some very considerable time to come. The use of another system, however, presents no very great, and certainly no *insurmountable*, difficulties, as any one may easily convince himself. Let us take, for example, the duodecimal system. Here it will be necessary to introduce two new names, for we are now about to count by *twelves* instead of by *tens*. The first ten numbers can retain their old names, but the names of the other two, *eleven* and *twelve*, which belong essentially to the old system, must be changed. Instead of these let us take *maun* and *bar* respectively, and let us call the system of counting by twelves the "*bar*" system.* In writing in figures we should have to introduce two new symbols, viz, one for ten and one for eleven, or maun as we will call it. Under the bar system, twelve or bar will be represented by 10 in the same manner as ten under the decimal system. Let the symbol *ν* represent ten and *ε* stand for eleven.

Our system would then be as follows :—

One .	1	Seven .	7	Bar-one . .	11	Bar-seven .	17
Two .	2	Eight .	8	Bar-two . .	12	Bar-eight .	18
Three .	3	Nine .	9	Bar-three .	13	Bar-nine .	19
Four .	4	Ten . .	*ν*	Bar-four . .	14	Bar-ten . .	1*ν*
Five .	5	Maun .	*ε*	Bar-five . .	15	Bar-maun .	1*ε*
Six .	6	Bar . .	10	Bar-six . .	16	Two-bar .	20

and so on, two-bar-one 21, &c., up to three-bar 30, four-bar 40, &c., ten-bar *ν*0, maun-bar *ε*0, and one "*gross*" 100, or bar times bar. The word "*gross*," being convenient and already used in English to denote a dozen dozen, has been retained.

Then one gross and one 101, &c., one gross one-bar 110, one gross two-bar 120, &c., one gross ten-bar 1*ν*0, one gross maun-bar 1*ε*0, and so on, two gross 200, three gross 300, &c., up to bar gross 1000, which we will call "*one range.*" A range of ranges might be called a bi-range, and so on a tri-range, &c. Anyone can frame a multiplication table, using the bar system in the same manner as is usually done in the decimal system, and anyone so doing will find that he will have no difficulty at all *so long as he confines himself*

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* The word "*bar*," first suggested by the Hindoostanee word *barah*, meaning twelve, has been retained in consequence of its English signification, being used here in much the same sense as in the phrase "a bar of music." The word "*maun*" was selected merely in order to have a short word, and one which should sound differently from the name of any other unit.

to the bar system; but if he should wish to translate into the decimal system some slight difficulty would present itself, though of course the conversion from one scale of notation to another is a simple mathematical operation. What is to be noticed is, that there is no inherent difficulty in the bar system any more than in the decimal system of notation.

We will now examine the decimal system in reference to Weights, Measures, and Coinage.

Starting from the fact that the decimal scale of notation is in general use, and, *by reason of this fact,* the decimal system is the one best suited for employment in our weights, measures, and coinage; for in this manner all the so-called compound rules of arithmetic, and those depending on our present system of tables, such as reduction, are done away with, and other rules, such as interest, discount, &c., are much simplified.

Seeing, then, that there is such a manifest advantage in favour of a decimal system of weights, measures, and coinage, how comes it that we have not that system? Who originated the system, or rather the medley or absence of all system which is in use in England at present? Topsy's answer, when asked who made her, would be appropriate here—"I s'pect I grow'd. Don't think nobody never made me." This was certainly the case. The foot, like the *pied* in France, was the length of the foot of the reigning king; and it seems to be a well-ascertained fact that this length, *the standard length of the kingdom,* changed, in some cases at all events, from reign to reign, according to the actual length of the king's foot. Then, too, in measures and weights there were local usages in different parts of the country, and from these at last there grew up one standard system for the whole country; but many local usages had to be subjects of severe legislation before they were finally abandoned.

It now becomes a question whether the heterogeneous system of weights, measures, and coinage now in use ought to be continued, or whether we ought not to abolish it, and replace it by a decimal system.

We will first consider the question of the weights and measures separately. Just let us take a glance at what it is necessary for an Englishman to know if he would be thoroughly acquainted with the weights and measures of his own country.

We have three distinct tables of weights, viz., Avoirdupois, Troy, and Apothecaries' Weight. We have, it may be said, one table for the measure of Length, but in reality there are more, for the link, the chain, and the pole are never used except by surveyors, and the hand is only used in measuring horses, &c. Then, too, the Admiralty knot differs from the geographical mile, which differs again from the ordinary mile. Next we have square measure, which, introducing the squares of the numbers used in long measure, introduces greater confusion. This is still more the case in cubic measure, for here the cubes of those numbers come into use. Again, wine measure differs from ale and beer measure, and, lastly, we have dry measure. This leaves out of account such things as the weight of a sack of flour, the size of a square of flooring, the different kinds of tons or loads, &c.

We will now give an example to point out the absurdity of the present system :—You are asked, "Which weighs the most, a pound of gold or a pound of feathers?" At first you feel indignant at such an insult. "Why, of course, they weigh the same." You are told "No;" and on thinking the matter over you remember that gold is weighed by troy weight and feathers by avoirdupois weight; and then if you have a good memory you recollect, or if not, you find on reference to the tables, that the pound avoirdupois weighs 7000 grains, while the pound troy weighs only 5760 grains, so that the pound of feathers weighs more than the pound of gold. Your questioner proceeds further, and says, "Which weighs most, an ounce of gold or an ounce of feathers?" Remembering the last, you say, "Why! the ounce of feathers." But no, the pound avoirdupois is heavier than the pound troy, but the ounce avoirdupois is lighter than the ounce troy. Is it not ridiculous? Is it not disgraceful for the greatest commercial nation on the face of the globe?

Again, a hogshead or a puncheon of beer contains less than a hogshead or a puncheon of wine. Such differences as these have no use whatever, and are extremely inconvenient.

In speaking of the weights and measures at present in use in England, we have several times made use of the word "system." This has been convenient, but it should not be understood to imply that there is any uniformity in any particular table of weights or measures. With a small exception, to be noticed presently, no such uniformity exists. Thus in avoirdupois weight we have—

16 drams	make	1 ounce.
16 ounces	,,	1 pound.
14 pounds	,,	1 stone.
2 stones, or 28 pounds .	,,	1 quarter.
4 quarters, or 112 pounds	,,	1 hundredweight.
20 hundredweights . .	,,	1 ton.

There is certainly very little uniformity or rule about this, but we might have chosen worse examples.

The exception spoken of just now is a testimony borne to the worth of the decimal system by engineers, surveyors, &c. They used a chain of 22 yards or 66 feet, and this they divided into 100 links for their own convenience. It will be seen that a link is no exact number of inches. Its length is 7·92 inches. Taking the chain as the unit of what may be called "surveyors' measure," we have—

100 links	make	1 chain.
10 chains	,,	1 furlong.

And in square or superficial measure—

10 square chains or 100,000 square links make 1 acre.

It is a case of rebellion from the existing system to the most convenient system for working with, viz., the decimal system. There are other cases of rebellion. Thus, the inch is not unfrequently divided into tenths and hundredths; and the metrical system has been adopted in some scientific works, notably in books on chemistry.

But on the subject of the inconvenience of our present system of weights and measures there is no need for long argument. We have all been schoolboys; and who is there who does not remember either in his own person or in the person of the majority of his schoolfellows the immense amount of trouble caused by the "Tables?" How often does the schoolmaster (supposing that he does not allow reference to the tables) hear the excuse, "Please, sir, I know how to do it, but I don't know my tables." Further, we very much suspect that it is scarcely necessary to go back to school-boy days. How many Englishmen are there who are perfect in all their tables? We appeal to every reader to judge for himself. It is to be feared that the proportion is very small indeed. If this state of things were inevitable there would be nothing to say against it: but it is far from being so.

There is a system already in use, not only by the nation which first employed it, but since then more or less completely adopted by several others. It is scarcely necessary to say that allusion is made to the Metric System introduced by the French.

The first idea of the metric system was to obtain one standard, that of length, which could always be reproduced by calculation, and so to avoid any difficulty as to the necessity of having a material standard which would be liable to be destroyed. In order to get this the length of the circumference of the earth was obtained from the measurement of an arc of a meridian, and this length was divided into 40,000,000 equal parts to obtain the unit of length, which received the name of "*mètre*." But as other measures of the circumference of the earth have given somewhat different results, it is plain that this first object of the metric system has failed. Not so the other objects. Having obtained the mètre, the standard of length, all other standards are derived from it, so that it is only necessary to keep *one* material standard, viz., the mètre.

For square or superficial measure we have the square mètre, but for the measure of land another unit is employed. Surveyors in France make use of a chain, a decamètre, or 10 mètres in length (about half our English chain), and the surface of a square decamètre is taken as the unit for measuring land, and is called an "*are*."

In solid measure the cubic mètre is used, or in measuring fire-wood, &c., the amount of wood which can be piled in cubic mètre is called a "*stère*." It will be seen that there is a difference. There is not a cubic mètre of wood, but the pile of wood, on account of the interstices, occupies a cubic mètre.

For dry and fluid measure the litre is the standard. It is the volume contained in a hollow cubic decimètre; or, in other words, it is the volume contained in a cube whose side is a decimètre or the tenth part of a mètre.

The gramme is the standard of weight, and is the weight of a cubic centimètre of distilled water at its maximum density.

The standard coin is the franc, a piece of silver weighing 5 grammes.

In the metric system the learning of tables is a very simple matter. It consists in acquiring the names of the different standards, and remembering that the Greek words, *deca*, *hecto*, and *kilo* must be prefixed to indicate respectively ten times, one hundred times, and one thousand times the standard; and that the Latin words, *deci*, *centi*, and *milli* prefixed to any standard signify the tenth, hundredth, and thousandth part respectively of the standard. This needs no comment; the facts speak for themselves.

A friend in England happened a short time ago to send me in India the following cutting from a local newspaper:—

"*The Metric System.*—The "Times," in discussing the proposed adoption of the metric system, says:—The essential inconvenience would be the utter subversion of all existing conceptions of length, magnitude, and proportion. At least nine-tenths of our fellow subjects are tied and bound to a multitude of common English facts, inextricably entangled with the soil, the village, and the town. They have a farm or garden of so many acres or roods; they dwell so many miles from the village, railway, or county town; they live by selling quarters of corn, bushels of potatoes, gallons of milk, or pounds of meat; their wives buy clothing for themselves and their children by the yard; they purchase the food of the household in pounds, and its luxuries in ounces; they measure their drink by pints, and their bread is bought in quartern or half quartern loaves. All these things are no more than names to people who never have occasion to consider any but large quantities; but to the middle and lower classes they are the elements of daily existence; they are the measures, not of mere pecuniary transactions, but of their resources, possessions, wants, and enjoyments. A quartern loaf, for instance, is not so much a thing of a given value; for its price may vary; but it is a known quantity of bread, good for so much food, and likely to last for such and such a time. The cost of a dress is a matter of choice, but not so its size. The rent of an acre of land is a variable quantity, but in the mind of every farmer an acre represents a score of associated realities. It will take a known time to plough, it will feed so many sheep, it will take so much manure, and so on. What, then, we are asked to do by Mr. J. B. Smith and his friends is to take all these people out of a world they know, in which all the dimensions, relations, and necessities of existence are familiar to them, and plunge them into a world in which everything will be strange to them, in which all their old bearings will be rendered obsolete, in which they will be puzzled every day to know where they are standing, how much they are eating and drinking, what they are selling, and what they are buying. How is a countrywoman to understand how many mètres she wants for her petticoat, or how many decagrammes of milk she must buy for her baby? If the measure could be enforced, the mass of the population would be placed, as it were, in a new country, with all the daily conditions of life uncertain."

I must first premise that I know no more of the argument of the writer in the "Times" than what I have learnt from this quotation, and any remarks that may be made in this article will necessarily refer *only* to this quotation.

The writer begins thus:—"The esssential inconveniences." From this we are, I think, justified in concluding that he goes on to state what he considers to be the strongest arguments against the adoption of the metric system.

In his next sentence it appears to me that there is at least one word too many, viz., the word "*inextricably*." For, in other countries with measures and weights as much unlike the metric system as our own, with a people not a whit more enlightened, and as much tied and bound to a multitude of common facts, just as inextricably entanged with the soil, the village, and the town as is the case in England, the change to the metric system has been already made and with the greatest success.

In aid of his argument the writer brings forward instances, *all*, or at least *most*, of which are such as are constantly recurring, and which are just those things which will be most quickly learnt. Allowing that a man accustomed to buy his pound of tea *may* be somewhat confused when he goes for the first time after the introduction of the new system to make his customary purchase, can we suppose that this confusion will last long? Will he be slow in forming his estimate of the weight of a kilogramme or hectogramme, when he constantly has to buy a kilogramme or so many hectogrammes?

The quartern loaf forms a great part of the writer's bill of fare. It seems that "it is a known quantity of bread, good for so much food, and likely to last for such and such a time." Precisely, and so is a loaf which weighs a kilogramme "good for so much food, and likely to last for such and such a time;" and it will be hard to persuade most people that a housekeeper would be more than a few days in finding out exactly *how much* food the new style of loaf is good for, and exactly *how long* it is likely to last. It would then become *in only a few days* "a known quantity of bread." The same would apply to all other instances, which occur frequently, and the very rarity of the occurrence of others diminishes their importance. The summing up of this truly alarming quotation is appalling. There would evidently be a famine, or some dire calamity. "All the daily conditions of life uncertain:" only think of it!

It does not seem to have occurred to the writer that precautions might be taken to mitigate the evils which he foresees; that it might be made generally known beforehand, for instance, by means of printed bills, &c., that a mètre is about 39⅜ inches; that a kilomètre is about 1100 yards, or 5 furlongs, or ⅝ths of a mile; that the hectare is about 2½ acres; the kilogramme about 2⅕ pounds; that 50 kilogrammes are about 1 hundredweight; and 1000 kilogrammes about a ton; whilst the litre is about 1¾ imperial pints, so that 4½ litres are about 1 gallon. Yet even such a simple precaution as this would do away with most of the inconvenience of which he so loudly complains.

Further, it must be remembered that while the *advantages* of the change will extend to all ages, the *inconveniences* will be confined to the generation existing during the transition stage, and to most even of them for a year or so at the furthest. *The shorter the transition stage the less will be the inconvenience.*

We will now turn to the question of the system of coinage. Here another consideration complicates matters, viz., what metal shall be employed as the standard. In England we have gold, whereas the French standard is silver. As it is to be expected that gold and silver will vary in their relative value, it is necessary to choose one of the two as our standard, so long as we employ them for the purposes of the currency. Opinion in England seems decidedly in favour of keeping gold as the standard; and, moreover, the franc, the standard coin of the French, is very small for such a purpose.

It has been proposed to coin a piece of 25 francs, and to divide this into tenths, hundredths, and thousandths. This would differ but little from our present sovereign, and if France would adopt gold as her standard, this system would seem the most feasible that could be devised.

It would be a great advantage to introduce the decimal system for coinage at the same time as the decimal system for weights and measures. There would thus be only one change. The metric system of weights and measures has already been largely adopted, and therefore it seems desirable for us to adopt *that* system in preference to any other decimal system. The franc, too, has been adopted to some extent, as, for instance, by Belgium, Switzerland, and Italy. It would be a step gained, therefore, if we could adopt a decimal system of coinage which would chime in as much as possible with the system already in use in several countries.

The afore-mentioned proposal would effect this. A coin might be struck exactly equal to 25 francs, and approximately to our present sovereign. This might be called the "standard," and would have the advantage of giving as its tenth part a piece equal to 2 francs 50 centimes exactly, *and approximately equal to our florin, and also* (*what is of no mean importance*) *to the rupee*, which may be called the universal coin of India. The hundredth part of the standard would be exactly 25 centimes, or approximately 2½ pence, and the thousandth part exactly 2½ centimes, or about our farthing. The tenth, hundredth, and thousandth parts might, if it were thought desirable, receive names, and for this purpose the words "dimes," "cents," and "mills" have been proposed.

Each coin should bear its name in words, and also its value as a decimal part of the standard stamped on it. It would be an improvement to place the abbreviation St. *after* the number indicating the standards, and *before* the numbers indicating the decimal parts. The St. would always then indicate the position of the decimal point.

The following might be the system of coinage :—

		Approximate English value.	Exact value in Francs, &c.	
			Frs.	Cents.
Gold Coins.				
One standard .	1 St.	£1	25	0
Five dimes . .	St. 0·5	10*s.*	12	50
Three dimes . .	St. 0·3	6*s.*	7	50
Silver Coins.				
One dime . . .	St. 0·1	2*s.*	2	50
Five cents . .	St. 0·05	1*s.*	1	25
Three cents . .	St. 0·03	7½*d.*	0	75
Two cents . .	St. 0·02	5*d.*	0	50
One cent . . .	St. 0·01	2½*d.*	0	25
Copper Coins.				
Four mills . .	St. 0·004	1*d.*	0	10
Two mills . .	St. 0·002	½*d.*	0	5
One mill . . .	St. 0·001	¼*d.*	0	2½

In this table there are seven coins which may be said to be in existence now, viz., the first two gold coins, the first two silver coins, and all the copper coins; for the difference between the coins now in existence and the coins spoken of above would be very slight.

It will be noticed that a new gold coin has been placed in the list, viz., a piece of 3 dimes, of the value of 7½ francs. As will be remembered, the French have a gold coin of the value of 5 francs. This is of a suitable circumference, but is rather thin; whereas the coin here proposed, being worth exactly half as much again, would be better in this respect, and would be found very convenient.

The new silver coins advocated here are those of 1, 2, and 3 dimes, of the value of 25, 50, and 75 centimes respectively. From their likeness to our twopenny, fourpenny, and sixpenny pieces, it is reasonable to conclude that they would be useful, and would cause no confusion.

The copper pieces being to all intents and purposes the same as those now in use call for no remark.

Supposing that England were to introduce this system for *herself and for her colonies and dependencies*, it is almost certain that all those nations which at present use the franc, having silver as their standard, would make gold their standard, and come into the system so as to obtain uniformity, for the change would be slight and insignificant for them. Moreover, let us think what is meant by the phrase Great Britain and her colonies and dependencies. There is only need to mention the United Kingdom of Great Britain and Ireland, India, Australia, New Zealand, and Canada to show the importance of the phrase. Then, consider the amount of commerce which is carried on by this assemblage of nations, both among themselves and with foreign nations, and it becomes a matter of extreme probability, almost amounting to certainty, that if Great Britain, her colonies, and dependencies were to adopt the metric system of weights and measures (already largely adopted by other nations), together with the decimal system of coinage here advocated, these systems would become universal over the whole civilised globe.

Whether such were the case or not the gain to Great Britain and her dependencies would be enormous. Let us compare the account books of the present system with those which would be used under the system advocated here. In this latter, besides the columns for the number of standards, there would be one column each for dimes, cents, and mills. This contrasts favourably with the present system; for, besides the column for pounds, there are now in reality four columns, viz., a *double* column for shillings, and a column each for pence and farthings. Further, under the decimal system it is merely a case of simple addition, whereas under the present system there are three different reductions to be made, viz., the division by 4 to reduce the farthings to pence, by 12 to reduce pence to shillings, and by 20 to reduce shillings to pounds. One result of the change would then be that bankers', merchants', tradesmen's, and, in fact, *all* account books, would be more easily and more correctly kept. The gain *to any one individual in any one day* might be small, but when we consider the gains of *all the people concerned*, the total gain becomes considerable *even in one day*; if, further, we consider *all the gains of all the people concerned for a year, or still more for all future time*, the total becomes simply overwhelming.

The advantage, too, to the commerce between England

and India alone would be very great in the uniformity that would thus be established in all accounts.

To India, too, considered alone, the benefit derived from the system advocated would be very great. The substitution of a rational system of weights and measures for that now in use would be highly beneficial, and the introduction of gold coins would be a great relief. It is hardly realised in England, because not experienced, what a nuisance in carriage and loss of time in counting is occasioned by the payment of any large sum of money in silver.

I do not at present recollect the exact proportion between the weight of the sovereign and that of the florin or rupee, but it will be near enough for our present purpose to use the following equation :—

The weight of 5 florins or rupees = the weight of 8 sovereigns = 2 ounces troy.

In order, then, to pay a sum of £40 we, in India, have to pay 400 rupees, that is to say, a weight of about 160 ounces troy as against a weight of about 10 ounces, which would be necessary to pay the same sum in England. In other words, we have now to use in India 16 times the weight of a coin that would be necessary to pay any sum were a gold coinage in circulation here. And since any weight of silver occupies more space than the same weight of gold, it follows that the comparison between the *bulks* of gold and silver coin necessary to pay any sum is still more in favour of the gold.

It would seem, then, that there is a large amount of argument in favour of England's making a change to a decimal system of weights, measures, and coinage, and that for the weights and measures the metric system should be adopted; whilst for coinage it should be a decimal system *in connection* with the system used in France, Belgium, Switzerland, and Italy, and which is a part of the metric system. It must here be noted that it is of importance to adopt a system in connection with one in use by *several* nations, rather than with one in use by *one nation only, although that one nation may be of the combined importance of the several nations;* for we thus have the adhesion of *several nations instead* of *one only*, and are to this extent nearer to the realisation of a universal system of weights, measures, and coinage; and the *universality* of the system is only second in importance to the fact of its being a *decimal* system.

The proposal to introduce a decimal system of weights, measures, and coinage seems to have set people to work to endeavour to find out all the difficulties of the scheme. This looking out for the difficulties of any new scheme is but reasonable, but it should be done in the spirit of a brave man, who, being convinced of the desirability of some object, looks first to see what difficulties lie in the way of its attainment, in order that he may be prepared beforehand, and be the more ready to meet and overcome them. Instead of this, we as a nation have been content to let the difficulties which look big and threatening prevent our adoption of a system which would be a great blessing to the land. We ought rather, having found the difficulties which oppose us, work heart and soul to remove them, and they would soon be found to be much less formidable than they appear. We all know that possession is said to be "nine points of the law;" and it is this and this only which has enabled the old system to hold out so long as it has done.

Even the opponents of the decimal system admit that there is no more, and perhaps, in fact, much less, difficulty in its working than in that of the system now in vogue. What they object to is the *change*, and not the *system* itself. Are we, then, for the sake of some *temporary inconvenience* to decline a *permanent advantage*? Are we, in fact, to suffer a *permanent* inconvenience because we are afraid of incurring a *temporary* trouble? Should we not rather constantly aim at attaining the permanent advantage, and at the same time endeavour to find out how we can make the temporary inconvenience as small as possible? In doing otherwise we merely add one more to the already long list of illustrations of the old saying, that "It is the lazy man who gives himself the most work."

Once understood, the new system would be easier than, and far preferable to, the old, and it is not *in itself* difficult to understand. The only difference lies in the fact that we are familiar with the old system, and consequently refer all questions of weights and measures to it; but once our conceptions of weights and measures formed in the new system, we should think in kilogrammes, mètres, litres, &c., and it would no longer be necessary to translate into the weights and measures of the old system. It is exactly the same as with languages. We, being English, think French difficult, and *vice versa*. In learning a foreign language the beginner generally translates every phrase mentally into his own tongue, but after he has properly acquired the other language he no longer makes any mental translation but seizes the meaning direct. So much is this the case that frequently an individual, although knowing thoroughly well the meaning of some passage of foreign language, may yet be totally unable to render the same exactly in his mother-tongue. The best way of learning a foreign language is undoubtedly to do without the aid of one's own as soon as possible, and the same is true with regard to the change to the decimal system of weights, measures, and coinage. The less comparison there is between the old system and the new the better, and the more we learn the new system, so to speak, from itself, by its use and without reference to the old, the quicker and the better shall we be able to understand it.

The great argument of our opponents seems to be that "the common people would not understand the system, and would not be able to use it." Now on what is this belief based? Is there any reasonable ground for supposing that this would be the case? The change has been successfully made in several other nations under as great difficulties as we should have to encounter. Do our opponents wish us to suppose that our own common people are below the common people of other nations in intelligence? For my own part, I cannot but think that, having the experience of other nations before our eyes, there is no reason to believe that we should fail on this score, and surely the common people of the United Kingdom are not willing to lie under the imputation thus thrust upon them. No; let us take all needful precautions; let us make the change as easy as possible; let us give all reasonable means to every man, woman, and child of learning the use of the decimal system, and then we need not fear to make the change. Moreover, I submit that, in that case, we should not be justified in delaying the change. It is neither reasonable nor desirable to make the lower classes the measure of the nation. We are bound to give them facilities for acquiring the use of the system, but, having done that, it is not our fault if they do not choose to avail themselves of those facilities; and the rest of the nation should not be deprived of an advantageous reform on their account.

Let us now see how the change might best be effected; by what precautions we can best overcome the difficulties that must inevitably arise.

In the first place, as we have seen, *the difficulty lies in the change itself, and only exists during the transition stage.* What is the conclusion? It is, *that the transition stage should be made as short as possible.* How may this best be done? Let it be agreed that the present system shall remain in force until some certain date, say, for instance, until the 1st of January, 1874, and that, from that date, its use shall be *illegal,* and the use of the decimal systems here proposed *compulsory*. Meanwhile, from the present date, numbers of specimens of the new weights, measures, and coinage might be made by the Government. These should not be for actual use in business, but merely for exhibition, in order to render the public familiar with them. We have already said that it is desirable to avoid translation as much as possible, and learn the new system from itself alone, and by its use.

Let the Government supply each shopkeeper with a set of such weights or measures, on the new system, as he would use in his business on the condition of his displaying them in his window. On the 1st of January, 1874, these sample weights and measures would become the property of the shopkeeper, and the Government would take up his old weights or measures and destroy them as such, utilising them in some other manner.

Further, every school should be supplied with a complete set of weights and measures according to the new system, and the scholars should be instructed in their use, and made familiar with their appearance and size.

Tables, of course, would be prepared showing the exact relations of the weights and measures of the new system to those of the old; but at the same time the comparison between the two systems should not be encouraged beyond what was absolutely necessary for the equitable settlement of claims.

If we do not adopt the decimal system for our weights, measures, and coinage we shall deserve even greater reproaches than have been heaped upon the workmen who destroyed the machinery of Arkwright and his brother inventors. For here we have a machine which is beautifully simple, with the working of which we are already familiar, and which would save labour to every man, woman, and child in the kingdom, and we refuse even to apply it to a new use.

There is no nation which has such a commerce as our own, and, consequently, there is no nation which would benefit so much by the adoption of a decimal system. Let us, therefore, no longer delay; let us recollect that the longer we delay the greater will the change be, and let us boldly make the change at once.

In conclusion, it is scarely necessary to state that the present article has not been meant as a dissertation on the decimal system. There are already many and excellent publications on the subject. The writer of this article is convinced that it can only be the fact that the great mass of the nation are content not to think on the subject, or has its time too fully occupied to do so, which has thus long delayed the introduction of the system into England. In this belief the present article has been written, in the hope that, by putting the matter in a plain, and, so to speak, everyday point of view, the thoughts of the public generally might be turned to the subject, which, in the writer's opinion, would be sufficient to seal the fate of our present system for ever.

III. THE CONSTRUCTION OF THE HEAVENS.

By RICHARD A. PROCTOR, B.A., Cambridge;
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"A knowledge of the construction of the heavens has always been the ultimate object of my observations."—Sir W. HERSCHEL (*Phil. Trans. for* 1811).

IT may appear strange, but is nevertheless strictly true, that though the name astronomy implies the science which deals with the laws of stellar distribution, yet astronomers as a body have given less attention to the discussion of these laws, or, in other words, to the solution of the problem of the construction of the heavens, than to any other department of their science. The observation of the stars has indeed occupied a large share of the labours of astronomers; but such observation has been directed to the exact determination of the position of individual orbs upon the vault of heaven. At the great public observatories the prosecution of such work—the importance of which, be it understood, I am very far from questioning—has been the object of many years of patient labour by many hundreds of skilful astronomers: catalogues in which star places are recorded by hundreds of thousands are now in existence, and the magnitude, colour, proper motion, annual parallax, and other relations of multitudes of stars have been carefully recorded. But these labours have not been carried out for the purpose of obtaining information respecting the structure of the sidereal universe. They have all related to the recognition and accurate placing of individual stars; and indeed it may be said, without exaggeration, that they have all been intended to subserve terrestrial purposes rather than to extend our knowledge of celestial relations.

And it is particularly remarkable how few of the astronomers whose names stand highest in the roll of scientific fame, have taken any considerable degree of interest in the problems presented by the stellar heavens. Hipparchus and Ptolemy studied the stars in order to obtain information respecting the earth. Copernicus neither formed nor attempted to form any theory of the sidereal system. He expressed, indeed, the opinion that the universe of stars is spherical, but he based this opinion on considerations far removed from the actual study of the stars. Kepler, in like manner, did not direct his attention to the distribution of the stars, and the evidence which that distribution may afford respecting the constitution of the heavens; he, like Copernicus, expressed an opinion respecting the sphere of stars, but the opinion was based on fanciful analogies, not on observed facts.* Galileo limited himself to the observation of the stars with his telescope, enunciating only the theory that the Milky Way consists of a multitude of stars, as demonstrated by his telescopic researches. Hevelius did not discuss in any way the relations presented by the stars. Huyghens, however, in his "Cosmotheoros," made many judicious reflections respecting the stellar system, and advanced opinions which were carefully based on observed facts. We owe to him the definite enunciation of the theory that the stars are suns like our own, probably, like it, the centre of planetary schemes. Huyghens, like his predecessors, failed to discuss attentively the configuration of the star groups, whether those seen by the naked eye or those revealed in the telescope, with the purpose of thence ascertaining the laws according to which the stellar universe is constituted. Newton, Halley, Flamsteed, and their contemporaries, paid in like manner very little attention, or none at all, to that stupendous problem, the solution of which Sir W. Herschel afterwards set before him as "the ultimate object of his observations." And passing at a step over the interval separating Newton's day from our own times, it may be said that the Herschels and the elder Struve have been the only astronomers who have attempted to form broad and connected views respecting the structure of the universe, while only half-a-dozen names need be added, if we would include those who have given attention to the subordinate problems associated with the great one of determining the laws of the sidereal system.

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* His reasoning is so remarkable that I venture to quote it in this place, for it affords a very suggestive insight into the nature of Kepler's mental organisation, especially when we consider that the work in which these ideas are put forward—the "Epitome," was published partly in 1618, and partly in 1620, while the three laws of Kepler were published in 1609 and 1619; in other words, that he was bringing out a farrago of fanciful and baseless speculations during the very period which saw him force from nature the key to one of the noblest of her secrets. After explaining that the stars are necessarily enclosed within the substance of a spherical shell having the sun at its centre, he proceeds to reason thus:—The radius of the concavity enclosing the sun is determined by a simple proportion. Saturn, the outermost planet, travels at a distance from the sun equal to 2000 times the sun's radius; therefore by the harmony of relations the distance of the sphere of the fixed stars is equal to 2000 times the distance of Saturn from the sun. But the thickness of the crystalline (the spherical shell enclosing the stars) can also be determined. All the matter of which the universe is formed is divided into three equal parts. One third is included in the body of the sun; another third forms the substance of the planets and of the celestial ether which fills up the space within the sphere of the fixed stars; the remaining third forms the crystalline. Now since the ether fills a space exceeding the sun's volume 64 trillions of times $[(4{,}000{,}000)^3]$, its density must be proportionately small compared with his. And the density of the crystalline must be a mean between the sun's density and that of the ether. Thus the crystalline has a density 8000 million times $[(4{,}000{,}000)^{\frac{3}{2}}]$ less than the sun's; and as its mass is equal to the sun's, its volume is 8000 million times greater. Hence, since its inner diameter is known, it is easy to calculate its thickness, which is found to be equal to the 6000th part of the sun's radius—or, according to nineteenth century measurements, to about seventy miles.

It would appear, as Struve points out, that Kepler in thus reasoning was chiefly striving to accommodate the Copernican theory with the ideas entertained in his day respecting the waters above the firmament spoken of in the Pentateuch.

But even more remarkable than the carelessness with which nearly all the great astronomers of the last three centuries have viewed this noble problem, is the fact that attention was first fairly called to the problem, and worthy attempts were first made towards its solution, by men who were not astronomers* in the true sense of the term, and whose names, with a single exception, remain in undeserved obscurity. How seldom do we hear the names of

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* Lest this remark should be misunderstood, I may as well explain in what sense I use the word astronomer. I was somewhat roundly taken to task when in the first edition of my "Other Worlds" I spoke of Whewell in one place, and of Humboldt in another, as not being astronomers. There cannot be any question that Whewell had a clearer insight into many astronomical subjects than many who must be described as astronomers; and a like remark applies to Humboldt, Brewster, and others, as well as to those of whom I speak above. Yet it is impossible for any astronomer to read many consecutive pages of matter written on astronomical subjects by Whewell, Humboldt, Brewster, Kant, and others, without feeling that they were emphatically *not* astronomers. What then, it may be asked, is my definition of an astronomer? It is one which immediately removes anything that might seem invidious in the distinction I draw between the above-mentioned eminent men, and others—not more eminent, some far less eminent—whom I should emphatically call astronomers. An astronomer is one who devotes the main portion of his scientific life and labour to the study of astronomy, either generally or in some special department. This definition excludes, and, as I take it, properly excludes,

Wright, Lambert, and Michell associated with those of the Herschels and Struve; how seldom, indeed, are they mentioned at all; and if the name of Kant is held in high honour, how little is this due to its association with astronomical theories! Yet I do not hesitate to say, that Wright, Kant, Lambert, and Michell did more to advance men's ideas respecting the constitution of the sidereal universe than all the astronomers who lived before the time of Sir W. Herschel.

We owe to Wright, of Durham, the enunciation of that theory of the universe which is so commonly presented in our text-books of astronomy, as representing the "outcome," so to speak, of the labours of the elder Herschel. Nor did Wright simply enunciate that theory; he based it on observation. All that was hypothetical in his reasoning was the idea with which he started that the stars are arranged with a certain general uniformity throughout the sidereal system. "It seems inconsistent," he said, "with the harmony observed in all the other arrangements of nature, that one scheme of stars should be arranged with perfect symmetry, while another is scattered irregularly." It is far safer—so Wright reasoned—to conclude that the seeming incongruity between the aspect of the Milky Way, which is unquestionably a zone of stars, is due only to the imperfect nature of our survey, both as respects extent of space and duration in time. "When we reflect," he proceeds, "upon the various configurations of the planets, and the changes which they perpetually undergo, we may be assured that nothing but a like eccentric position of the stars could occasion such confusion among bodies otherwise so regular; in like manner we may conclude, that as the planetary system if viewed from the sun would appear

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those who turn for awhile from their special branches of research to the study of some special astronomical subject, however skilfully they may treat that subject. It also excludes those (and again, as I take it, the exclusion is right and proper) who have made all science their subject. But unlike other definitions which I have heard advanced, it does not exclude any class of astronomical workers or thinkers. If we take a familiarity with any special branch of astronomical lore, whether observational or mathematical, or theoretical or historical, as essential to the character of the true astronomer, we must in every case exclude many who have given nearly the whole of their scientific life and labour to the advancement of the science of astronomy. We might thus adopt a definition excluding Adams and Leverrier, or another excluding Airy or Challis, or another excluding Huggins and De la Rue, or another excluding Dawes and Webb, and Knott and Browning. Newton could be excluded because he was not an observer of the heavens; Sir W. Herschel because he was not an adept in manipulating the formulæ of Laplace and Lagrange. In fine, we might successively exclude every student of astronomy that has ever lived, with perhaps the single exception of the younger Herschel.

perfectly symmetrical, so there may be some place in the universe where the arrangement and motions of the stars may appear most beautiful. If we suppose the sun to be plunged in a vast stratum of stars of inconsiderable thickness compared with its dimensions in other respects, it is not difficult to see that the actual appearance of the heavens may be reconciled with a harmonious arrangement of the constituent bodies of such a system with respect to some common centre, provided it be admitted at the same time that the stars have all a proper motion. In such a system it is manifest that the distribution of the stars would appear more irregular the farther the place of the spectator was removed from the centre of the stratum towards either of the sides. It is also evident that the stars would appear to be distributed in least abundance in the opposite directions of the thickness of the stratum, the visual line being shortest in those directions; and that the number of visible stars would increase as the stratum was viewed through a greater depth, until at length, from the continual crowding of the stars behind each other, it would ultimately assume the appearance of a zone of light."*

It will be obvious that we have here a complete enunciation of what has been called the Grindstone theory of the stellar system. The theory is based by Wright on observed facts, precisely as it was afterwards based by Sir W. Herschel on other observed facts. Assuredly whatever credit appertains to the invention of the theory must be in justice ascribed to Wright, who thus in 1750 reasoned out and clearly described the views to which Herschel was led in 1784. Wright, indeed, did not convince his contemporaries. Either they were unwilling to examine the reasoning he advanced, or they could not recognise its force; but neither remissness nor slowness of apprehension on their part can afford just ground for depriving Wright of the credit due to his ingenious analysis of known facts.

Kant's speculations, so far as they relate to the present constitution of the universe, must be regarded as simply an extension of Wright's theories. Kant had read Wright's work, the "Theory of the Universe," which had been reprinted in a Hamburg journal of the year 1751, and he admits that his views respecting the universe of stars were suggested by Wright's theories; but he found himself

* I have not followed here Wright's actual text, not having present access to his work. The above passage is taken from the abstract of Wright's theory in Professor Grant's excellent "History of Physical Astronomy."

unable to indicate "to what extent his system is a reproduction or amplification of Wright's." There can be no question that unconscious memory had a much larger share in the production of Kant's ideas as published in 1755, than he himself (in the absence of Wright's work to refer to) could probably have imagined.* The most important point to be noticed in Kant's work is his extension of Wright's speculations to other orders of systems than observation had yet revealed. Wright had considered that the nebulæ indicate the existence of other systems, not necessarily like our own star system, but of the same order in the scheme of creation. Kant considered that these star systems are members of a new system of a higher order. "We trace here," he added, "the first terms of a series of worlds and systems, and these first terms of an infinite series enable us to infer the nature of the rest of the series."†

Strangely enough while Kant borrowed his views almost wholly, though unconsciously, from Wright, he seems to have been disposed to regard Lambert's views—which in reality were unlike his own—as borrowed from him. In his correspondence with Lambert, Kant remarked in 1763, that "the accordance between their ideas extended even to the most minute details." It will be seen, however, that in forming this opinion Kant misinterpreted the theses of Lambert.

Lambert, like Huyghens, Wright, and Kant, regarded the stars as suns resembling our own sun in importance, and like it surrounded by planetary systems. Each sun with its family of planets formed in Lambert's theory *a system of the first order*. He considered that our sun belongs to a vast globular group or cluster of stars, forming *a*

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* Professor Huxley, in his fine essay on "Geological Reform," remarks that Grant, in his "History of Physical Astronomy," makes but the briefest reference to Kant. The reason for this may probably be found in the circumstance that, in describing Wright's ideas, Grant had already presented all those of Kant's views which could properly find a place in a history of physical astronomy. The student who is anxious to inquire into those more speculative ideas of Kant which are not to be found in Wright's "Theory of the Universe," should refer to Kant's original work, "Allgemeine Naturgesichte und Theorie des Himmels; oder Versuch von der Verfassung und dem mechanischen ursprunge des ganzen Weltgebündes nach Newton'schen Grundsatzen Abgehandelt."—Kant's Sämmtliche Werke, Bd i., p. 207.

† I omit all reference to the ideas of Wright, Kant, Lambert, and others, as to the existence of central suns, simply because those ideas were purely speculative. I may add here, however, that analogy now no longer requires that we should consider every system as necessarily governed by a central orb. We now know from observation that many systems of orbs exist in space which have have no dominating centre.

system of the second order, including all those stars, spread over all parts of the heavens, which do not belong to the milky way. He further held that there are many systems of the second order, and that these are not distributed throughout all space, but are all found near a certain principal plane or mean level, and being ranged one behind the other to a great depth, form by their concourse the Milky Way. This is *a system of the third order*. Analogy suggests, he added, that there are in the universe many Milky Ways; "perhaps, for instance, the nebula in Orion may be a Milky Way, nearer to us than the rest. Should this be the case, telescopic research will reveal many others, forming together *a system of the fourth order*." And he proceeded thence to the inference that there may be systems of yet higher orders.

It will be observed that in regarding the Milky Way as formed, not *directly* of the concourse of many stars, but of the concourse of many clusters of stars, Lambert adopted a totally different conception of its nature than Kant had formed. Nor was this view of Lambert's, any more than his other opinions, merely speculative. He based it on the observed irregularity of the Milky Way, on the different richness of its various parts, and on its branching figure. In passing, it may be observed that Lambert here anticipated the conclusions to which Sir William Herschel was led after he had abandoned the principle of star gauging.

Lambert thus describes the grandeur of the universe of systems as pictured in his theory:—"How far soever we may extend the scale," he says, "we must necessarily stop at last. And where? At the centre of centres, at the centre of creation, which I should be inclined to term the capital of the universe, inasmuch as thence originates motion of every kind, and there stands the great wheel in which work the teeth of all the rest. From thence the laws are issued which govern and uphold the universe; or rather, there they resolve themselves into one law of all others the most simple. But who would be competent to measure the space and time which all the globes, all the worlds, all the worlds of worlds employ in revolving around that immense body—the Throne of Nature and the Footstool of the Divinity! What painter, what poet, what imagination is sufficiently exalted to describe the beauty, the magnificence, the grandeur, of this source of all that is beautiful, great, and magnificent; and from whence order and harmony flow in eternal streams through the whole bounds of the universe."

Michell limited his attention to the lucid stars, not enunciating any complete theory respecting the galaxy. The most important of his theoretical views, or rather the most important of the facts which he established,* is that which relates to the existence of laws of arrangement (even among the stars visible to the naked eye), according to which the stars form systems, separated from each other by relatively vacant spaces. "We may conclude," he says, "that the stars are really collected together in clusters in some places, where they form a kind of systems; whilst in others there are either few or none of them, to whatever cause this may be owing, whether to their mutual gravitation or to some other law or appointment of the Creator. He then proceeds to inquire whether the sun "likewise makes one of some system." He considers that this is probably the case, and he endeavours to separate those stars which probably belong to the same system as the sun from those which do not. "There are some marks," he says, "by which we may with great probability include some and exclude others,—while the rest remain more doubtful. Those stars which are found in clusters and surrounded with many others at a small distance from them, belong probably to other systems and not to ours. And those stars which are surrounded with nebulæ are probably only very great stars, which upon account of their superior magnitude are singly visible, whilst the others which compose the remaining parts of the same system are so small as to escape our sight. And those nebulæ in which we can discern only a few stars even with the assistance of the best telescopes, are probably systems which are still more distant than the rest." On the other hand, he inferred that those stars "which being placed at a greater distance from each other compose the larger constellations, and such as have few or no smaller stars near them when examined with telescopes, belong probably to our own system. Variable stars he also regarded as in all probability members of the system of stars to which our sun belongs; though the reasoning on which he based this opinion is not such as can now be admitted; for he considered their variations of brilliancy to be due to variations of distance (a cause which would necessarily be more effective in the case of stars relatively near to us); but we now know that this explanation is not the true one. He also judged red stars to be much larger and nearer than their apparent brightness would suggest, and hence inferred that they also belong to the system of stars which includes our sun.

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* Amongst the facts which Michell established must be included the existence of binary star systems. Nothing can be more complete or demonstrative than Michell's reasoning on this subject; and I can conceive no reason why the credit of the discovery should be refused to the man who deduced it by exerting the noblest of human faculties—the power of abstract reasoning, in order that it should be handed over to another (however eminent) who deduced it from direct observation. It is true Michell failed to convince his contemporaries, and that his reasoning if it had not been subsequently confirmed by Sir W. Herschel's observations might have remained to this day unappreciated, save by the few. But this does not do away with the fact that Michell's demonstration was complete; and his credit ought not to be diminished because the many could not grasp the full value of the proof. A very slight extension of such a method of judging might deprive the Herschels in their turn of the credit now (as I think unjustly) assigned to them for the discovery, to make it over to the first person who (say) by obtaining photographic records of double stars, should enable every one to see for himself that one component circles around the other. Surely the reputation of the Herschels does not require that any credit should be assigned to them which is justly due to another. Michell has indeed been particularly unfortunate in such matters, since, to mention no other instances, the so-called Cavendish experiment for weighing the earth was not only devised by him, but the very instrument with which Cavendish conducted the experiment was constructed under Michell's superintendence.

In passing to the work of Sir W. Herschel as a student of the sidereal heavens, I cannot but express some degree of surprise that so little has been done to bring the records of his labours properly before the student of astronomy. His papers merely collected into a volume would form a most important accession to astronomical literature. But if suitably edited and illustrated by the work of his son, and of others who have succeeded in the same field of research, the volume would do more to advance the study of sidereal astronomy than any work which has been published during the last century. It must be added that nearly all that has hitherto been done in making Herschel's words and work public, has been rather an injustice to his memory than otherwise. It seems to have been supposed that his own account of his work might be treated as we should treat such a work as Sir John Herschel's "Outlines of Astronomy," and that extracts might be made from any part of any paper, without reference to the position which that paper chanced to occupy in the complete series. It does not seem to have been noticed that not only was there a progression in the ideas as well as in the work of the great astronomer, but that there was a complete change in his opinions during the progress of his labours. Hence views expressed by him in his earlier papers are not uncommonly in strong contrast with those which he advocated in later years; opinions which he regarded as certainly just at one time were rejected as most probably incorrect after a few years of fresh labour; and whereas in 1785 he enunciated with some definiteness a theory respecting the constitution of the universe, he not only abandoned this theory (implicitly) in 1811, not only gave up the very principles on which it had been based, but he did not consider himself in a position during any subsequent part of his career to state with the same degree of definiteness any theory whatever respecting the constitution of the heavens.

It is to be premised, however, that even the theory of 1785* is not properly described in our text-books of astronomy, and that some of the accounts which purport to be descriptions are the merest travesties of the noble conceptions of Sir W. Herschel.

The sole point in the remarkable paper of 1785 which seems in any degree to correspond with the account usually given, is the hypothesis on which the principle of star-gauging is based. Herschel adopts a general uniformity of stellar distribution within the sidereal system as a means of forming some idea of the shape of that system. If there were actual uniformity, it would be sufficient to turn a telescope successively to different parts of the heavens, to obtain a sufficiently accurate idea of the extension of the stellar system in those different directions; for, obviously, the farther away the boundary of the system might lie in any direction, the more stars would be seen in that direction. But though Herschel thus adopts a principle resembling that usually associated with the method of star-gauging, and though he arrives at a conclusion in some sense resembling that which has received the name of the Grindstone Theory (though it would more properly be called the Cloven Disc Theory), yet it is only on the most cursory reading that either the principle of generally equable distribution, or the conclusion that our sidereal system forms a cloven stratum of stars, can be regarded as according with Herschel's real views. He fully recognised the existence of subordinate systems within our sidereal system. This is shown by his remark that it is "a very extensive, branching, compound *congeries* of many millions of stars, which most probably owes its origin to many remarkably large as well as pretty closely scattered small stars that may have drawn together the rest."

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* It will be observed that I pass over the paper of the year 1784, in which Herschel first began to discuss the constitution of the heavens. That paper is so obviously a mere introduction of his subject, so obviously preliminary, that one cannot but be amazed to find how much stress is laid upon it in many works on astronomy, and especially among French writers. We doubtless owe this to Arago's misapprehension of the purport of the paper. Struve has pointed out, also, very justly, that Arago has misconstrued the details of Herschel's theories. There scarcely exists, indeed, a less trustworthy account of Herschel's works and theories than Arago's, whom yet many English writers accept as an authority on the subject.

Again, let the reader carefully study the following extract from the paper of 1785, and he will find that whereas it is perplexing in the extreme if the sidereal system be regarded as a mere cloven stratum of stars, pretty uniformly distributed, it becomes perfectly clear (and wonderfully striking) when we remember that Herschel considered the milky way to be compound in structure and branching in figure:—

"If it were possible to distinguish between the parts of an indefinitely extended whole, the nebula we inhabit might be said to be one that has fewer marks of profound antiquity upon it than the rest. To explain this idea, perhaps, more clearly, we should recollect that the condensation of clusters of stars has been ascribed to a gradual approach; and whoever reflects upon the numbers of ages that must have passed before some of the clusters could be so far condensed as we find them at present, will not wonder if I ascribe a certain air of youth and vigour to many very regularly scattered regions of our sidereal stratum."

Yet more strikingly opposed to the common conceptions of Herschel's earlier theory, is the following passage from the paper of 1785:—"Our system after numbers of ages may very possibly become divided so as to give rise to a stratum of two or three hundred nebulæ; for it would not be difficult to point to so many beginning or gathering clusters in it. This view of the subject throws a considerable light upon the appearance of that remarkable collection of many hundreds of nebulæ which are to be seen in what I have called the nebulous stratum of Coma Berenices. It appears from the extended and branching figure of our nebula, that there is room for the decomposed small nebulæ of a large, reduced, former great one to approach nearer to us in the sides than in other parts. Nay, possibly, there might originally be another large joining branch, which in time became separated by the condensation of the stars; and this may be the reason of the little remaining breadth of our system in that very place; for the nebulæ of the stratum of Coma are brightest and most crowded just opposite our situation, or in the pole of our system. As soon as this idea was suggested," he adds, "I tried the opposite pole, where accordingly I have met with a great number of nebulæ, though under a much more scattered form."

It will be quite obvious, I think, that Herschel entertained at this time ideas altogether different from those usually ascribed to him. In particular, it is to be noticed that he regarded the nebulæ in two aspects at this time. There were some which he held to be parts of a much larger nebula, possibly parts of our own Milky Way. Others he held to be external Milky Ways, and therefore themselves made up of subordinate nebulæ. At this stage of his career, however, he seems to have entertained no doubt as to the stellar character of any nebulæ; and it is to the ideas he thus early promulgated respecting the nebulæ, that we must ascribe the common but altogether erroneous opinion, that Herschel regarded all the nebulæ as external galaxies of suns. He never entertained so general a theory as this; but even the theory he did entertain in 1785 respecting some of the nebulæ was modified ere long as respects a very large proportion of those objects.

He had not changed his views, however, in 1789, when he compared the nebulæ of various orders to plants in various stages of growth. The following passage does not relate, as has been asserted, to his hypothesis of the development of nebulæ into stars, but relates to various orders of stellar systems. "This method of viewing the heavens," he says, referring to the view that differences of antiquity may account for the different appearances of nebulæ, "seems to throw them into a new kind of light. They now are seen to resemble a luxuriant garden, which contains the greatest variety of productions in different flowering beds; and one advantage we may at least reap from it is, that we can, as it were, extend the range of our experience to an immense duration. For to continue the simile I have borrowed from the vegetable kingdom, is it not almost the same thing whether we live to witness successively the germination, blooming, foliage, fecundity, fading, withering, and corruption of a plant, or whether a vast number of specimens, selected from every stage through which the whole plant passes in the course of its existence be brought at once to our view.

But the time was approaching when Herschel was to form entirely new views respecting the constitution of the heavens. I pass over the paper of 1796—though if space permitted I might quote passages from it, suggesting in a very interesting manner the progression of Herschel's ideas—and turn to the paper of 1802. There can be no mistaking the import of the following passages from this important paper:—"The stars we consider as insulated," says Herschel, "are also surrounded by a magnificent collection of innumerable stars, called the Milky Way, which must occasion a very powerful balance of opposite attractions, to hold the intermediate stars in a state of rest. For though our sun, and all the stars we see, may truly be said to be in the plane of the Milky Way, yet I am now convinced by a long inspection and continued examination of it that the Milky Way itself consists of stars very differently scattered from those which are immediately about us." . . . . "On a very slight examination it will appear that this immense starry aggregation is by no means uniform. The stars of which it is composed are very unequally scattered, and show evident marks of clustering together into many separate allotments." . . . . "The milky appearances deserve the name of clustering collections, as they are certainly much brighter about the middle and fainter near their undefined borders. For in my sweeps of the heavens it has been fully ascertained that the brightness of the Milky Way arises only from stars; and that their compression increases in proportion to the brightness of the Milky Way." . . . . "We may indeed partly ascribe the increase both of brightness and compression," in these clustering regions," to a greater depth of the space which contains these stars; but this will equally tend to show their clustering condition; for, since the increase of brightness is gradual, the space containing the clustering stars must tend to a spherical form if the gradual increase of brightness is to be explained by the situation of the stars."

It was in this paper that Herschel first put forward the hypothesis that many nebulæ are formed of some substance possessing "the quality of a self-luminous milky luminosity," and "possibly at no great distance from us." But the requirements of space render it advisable that I should leave untouched the whole of those considerations which Herschel adduced, in this paper and elsewhere, in favour of his nebular hypothesis.

That portion of Herschel's observing career which we have now reached may fairly be regarded as including the most important of his researches into the constitution of the heavens. His mental powers were now at their prime. He had acquired great experience. His circumstances were such that he could give his whole attention to scientific work. Moreover, he had seen the importance of being solely guided by known facts, since the theory which he had adopted more than a quarter of a century before (and almost in the beginning of his observations on the stars) had had to be abandoned.

Nine years of earnest labour passed before he again spoke at any length on the subject of the star-depths. It will be admitted that we should attach especial value to the announcements he then made. Yet the striking words with which he prefaces the paper of 1811 seem almost to have escaped notice:—"I must freely confess," he says, "that by continuing my sweeps of the heavens my opinion of the arrangement of the stars and their magnitudes, and of some other particulars, has undergone a gradual change; and, indeed, when the novelty of the subject is considered, we cannot be surprised that many things formerly taken for granted should, on examination, prove to be different from what they were generally but incautiously supposed to be. For instance, an equal scattering of the stars may be admitted in certain calculations; but when we examine the Milky Way, or the closely compressed clusters of stars, of which my catalogues have recorded so many instances, this supposed equality of scattering must be given up. We may also have surmised nebulæ to be no other than clusters of stars disguised by their very great distance; but a longer experience and a better acquaintance with the nature of nebulæ will not allow a general admission of such a principle, although undoubtedly a cluster of stars may assume a nebulous appearance when it is too remote for us to discern the stars of which it is composed."

In the paper of 1811, however, Herschel does not (save in these prefatory remarks) consider the structure of the sidereal heavens. The paper is devoted exclusively to the discussion of the nebular hypothesis as to the formation of stars. It was not until 1814 that he endeavoured to extend his reasoning so as to include the subject of stellar grouping. "The observations contained in this paper," he says in 1814, "are intended to display the sidereal part of the heavens, and also to show the intimate connection between the two opposite extremes, one of which is the immensity of the widely diffused and seemingly chaotic nebulous matter; and the other, the highly complicated and most artificially constructed globular clusters of compressed stars." In this paper he enters also into a discussion of ambiguous objects,—that is, objects "of such a construction or at such a distance from us, that the highest power of penetration which hitherto has been applied to them, leaves it undecided whether they belong to the class of nebulæ or stars."

But the chief interest of the paper of 1814 resides (in my judgment) in the remarks which Herschel makes respecting the clustering condition of parts of the heavens. He explains that his expression "forming clusters," was used "to denote that some peculiar arrangement of stars in lines making different angles, directed to a certain aggregation of a few central stars, suggested the idea that they '(the former)' might be in a state of progressive approach to them '(the latter).' This tendency to clustering seems chiefly to be visible in places extremely rich in stars. In order, therefore, to investigate the existence of a clustering power, we may expect its effects to be most visible in and near the Milky Way." I invite the reader's special attention to the circumstance that the Milky Way is here pointedly referred to as a stellar region distinct in its characteristics from the region of stars forming our constellations. In studying Herschel's papers we have to be continually on the watch for indications of the sort, since he does not always judge it necessary to make definite assertions of his opinions on such points.

He then describes the irregular clusterings of stars, noting in particular, that "though they are in general very promiscuously scattered, they are yet sufficiently drawn together to show that they form separate groups," while in many places a falling off in the number of stars surrounding the clusters "indicates a tendency to future insulation." "Those which are in and very near the Milky Way," he says, "may be looked upon as so many portions of the great mass drawn together by the action of a clustering power, of which they tend to prove the existence. In describing the various orders of irregular clusters, Herschel is particular to notice *rows* and *streams, ridges* and *shelvings*, of stars, as indications of a preponderating clustering power.

It is most important to notice here that Herschel had not yet replaced the theory of 1785 by any complete new theory.* He says at the close of the paper of 1814—"The extended views I have taken in this and my former papers of the various parts that enter into the construction of the

* The careful Struve did not fail to recognise the distinction between the theory of 1785 and Herschel's subsequent labours. "Ou peut demander," he says, "pourquoi les astronomes ont-ils maintenu généralement l'ancien système sur la Voie Lactée, énoncé en 1785, quoiqu'il eût été entierement abandonné par l'auteur luimême comme nous l'avons démontré. Je crois qu'il faut en chercher l'explication dans deux circonstances. C'était un système entier, imposant par la hardiesse et la précision géométrique de sa construction, et que l'auteur n'avait jamais révoqué dans sa totalité. Dans ses traités publiés depuis 1802, on ne rencontre que des vues partielles, mais qui suffisent, en les comparant entre elles, à comprendre l'idée finale du grand astronome." I should point out, however, that Struve somewhat over-estimates the precision of the theory of 1785, and that he also fails to notice the circumstance that the papers of 1817 and 1818 are distinct in all respects from Herschel's former work.

heavens, have prepared the way for a final investigation of the universal arrangement of all these celestial bodies in space." He was now in his *seventy-sixth* year, however, and though still in the full possession of his wonderful powers, the time that remained to him for investigating the universal arrangement of the heavens was short indeed, when the wideness of the subject is considered. But he was not even yet fully prepared to enter on the work. For he proceeds to mention as a reason for not doing so, that he is "still engaged in a series of observations for ascertaining a scale whereby the extent of the universe, as far as it is possible for us to penetrate into space, may be fathomed."

In the papers of 1817 and 1818, the last of the series, and written, be it remembered, when Herschel was in his seventy-eighth and seventy-ninth years, he describes the principle here referred to, and its application to estimate the profundities of various parts of the stellar heavens. The principle was essentially this—that the telescopic powers necessary to reveal and to resolve star groups, or particular star orders within groups, afford an indication of the distance at which those groups or orders lie. I conceive that no question can exist that the principle is unsound, and that Herschel would himself have abandoned it, had he tested it earlier in his observing career, and when *not* his mental power, *but* his mental elasticity, was greater than at the advanced age which he had now reached. I have not here space to enter into all the objections which present themselves against it. Presently, in considering Sir John Herschel's theoretical views, I shall have to adduce a conclusive instance of the unsoundness of the principle. Let it here suffice to remark, that repeatedly in applying it, Sir W. Herschel found regions of the heavens very limited in extent, where the brighter stars (clustered like the fainter) were easily resolved with low powers, but where his largest telescopes could not resolve the faintest. These regions, if the principle were true, must be long spike-shaped star groups, whose length is directed exactly towards the astronomer on earth,—an utterly incredible arrangement, even if we could believe in the dynamical possibility of such grouping.

Herschel did not live to carry out that final investigation of the universal arrangement of all the celestial bodies in space which he had looked forward to in 1814. In 1820 he read, as first President of the Astronomical Society, a paper on the double stars, and soon after his health broke down, insomuch that, though he lived till 1824, he was incapable of great or prolonged mental exertion.

Sir John Herschel's labours among stars and nebulæ were directed almost wholly to the completion of the survey of the heavens. I do not know that there is a single passage in his works in which he touches on the subject of the constitution of the heavens otherwise than as it were incidentally. He nowhere definitely enunciates a theory of the universe.

Two circumstances, however, in Sir John Herschel's work require to be attended to.

The first relates to the distribution of the brighter orders of stars over the heavens. In his "Outlines of Astronomy," he says that the stars of these orders, including those down to and those somewhat below the range of the naked eye), increase largely in number as the Milky Way is approached. In his "Observations at the South Cape," he asserts the reverse. "On a general view it appears," he says, "that the tendency to greater frequency, or the increase of density in respect of statistical distribution in approaching the Milky Way, is quite imperceptible among stars of a higher magnitude than the 8th, and except on the very verge of the Milky Way itself, stars of the 8th magnitude can hardly be said to participate in the general law of increase. For the 9th and 10th the increase, though unequivocally indicated over a zone extending at least 30° on either side of the Milky Way, is by no means striking. It is with the 11th magnitude that it first becomes conspicuous, though still of small amount when compared with that which prevails among the mass of stars of magnitudes inferior to the 11th, which constitute 16-17ths of the totality of stars within 30° on either side of the galactic circle." He then adds as a conclusion, "following inevitably from this" (and this conclusion is to be carefully noted, since, if just, it is of the utmost importance), "that the larger stars are really nearer to us taken *en masse*, and without denying individual exceptions, than the smaller ones. Were this not the case, were there really among the infinite multitude of stars constituting the remoter portions of the galaxy numerous individuals of extravagant size and brightness, as compared with the generality of those around them, so as to overcome the effect of distance and appear to us as large stars, the probability of their occurrence in any given region would increase with the total apparent density of stars in that region, and would result in a preponderance of considerable stars in the Milky Way, beyond what the heavens really present, over its whole circumference."

The discrepancy between the statements in the "Outlines" and in the "Observations" is so complete that I ventured to communicate with Sir John Herschel respecting it, though I was not without a tolerably definite idea as to its origin. He replied as follows:—"I thank you for calling attention to that section in my "Outlines." Undoubtedly there *is* a discordance of statements which requires correction. But the appeal there" (that is, in the "Outlines") "is rather to a vague naked eye impression than to the statistical result of actual enumeration; and assuredly on a cursory view of the heavens on a clear night, stars down to the 7th and 8th magnitude do affect the eye, though we cannot fix them by reason of that strange law which curtails a star *directly* looked at of a very large aliquot part of its photometric effectiveness." It will be seen that Sir John Herschel here maintains at once the reality of the aggregation of the brighter stars on the *visible* Milky Way, and the justice of the statistics which related to the Milky Way regarded as a *zone*. This is undoubtedly the true explanation of the matter, as my equal surface chartings have since abundantly demonstrated. The brighter orders of stars, down to the 11th, do unquestionably crowd upon the real Milky Way,—that altogether irregular region of star streams and star clusterings which has been aptly compared to a band of broken *cirrus* clouds; but if we lose sight of these irregularities, if we conceive of the Milky Way as of a uniform zone, and take the average distribution of the brighter stars over that zone, we no longer find that exceptional degree of richness, for the gaps and *lacunæ* of the Milky Way are as poverty stricken, notwithstanding their position in that imagined *zone* of richness, as the brighter parts are rich in respect of these higher orders of stars. But this explanation shows that the conclusion based by Sir John Herschel on the zone-statistics should be *not merely abandoned but replaced by its converse*. Let the reader carefully re-study it in the light of the above considerations, and he will see at once that this is the case.

The second point to which I would invite attention in Sir John Herschel's work is his discussion of the phenomena presented by the two Magellanic clouds. His reasoning cannot be too carefully considered. It runs thus:—"Taking the apparent semi-diameter of the Nubecula Major as three degrees, and regarding its solid form as, roughly speaking, spherical, its nearest and most remote parts differ in their distance from us by little more than a tenth part of our distance from its centre. The brightness of objects situated in its nearer portions, therefore, cannot be *much* exaggerated, nor that of its remoter *much* enfeebled, by their difference of distance; yet within this globular space we have collected upwards of 600 stars of the 7th, 8th, 9th, and 10th magnitudes, nearly 300 nebulæ, and globular and other clusters *of all degrees of resolvability*, and smaller scattered stars innumerable of every inferior magnitude, from the 10th, to such as by their multitude and minuteness constitute irresolvable nebulosity, extending over tracts of many square degrees. Were there but one such object, it might be maintained without utter improbability that its apparent sphericity is only an effect of foreshortening, and that in reality a much greater proportional difference of distance between its nearer and more remote parts exists. But such an adjustment, improbable enough in one case, must be rejected as too much so for fair argument in two cases. *It must, therefore, be taken as a demonstrated fact, that stars of the 7th and 8th magnitude and irresolvable nebulæ may co-exist within limits of distance, not differing more in proportion than as nine to ten.*"

I pass to the work of the elder Struve, but shall only deal with that portion which relates to the distribution of the stars.

Having found reason to believe that stars of the brighter orders are more crowded on the Milky Way zone than elsewhere, Struve tested the matter by comparing the numbers of stars in different hours of right ascension in Weisse's Catalogue of 31,085 stars, down to the 9th magnitude, included between 15° north and 15° south of the equator. After estimating the numbers of stars which might be supposed to have escaped recognition in the different "hours," and so raising the total number of stars to 52,199 (of which 21,114 were hypothetical), he found a marked excess of richness in the Milky Way "hours." Thus, taking the four hours, 5, 6, 7, and 8 (crossed centrally by the Milky Way near Orion), and the four hours, 17, 18, 19, and 20 (crossed centrally by the Milky Way near Aquila), he found an average of 3031 stars for each hour; while the average for the remaining sixteen hours was but 1747 stars.

So far Struve's procedure was legitimate enough. But he now extended his reasoning somewhat too daringly. For he first regarded all the stars in each hour division as gathered on the equator, though the divisions extended *thirty* degrees in declination, and having thus a fine equatorial ring of 52,199 stars unequally rich in different parts, he conceived this ring converted into a flat disc by a radial spreading of the stars towards the several parts of the ring, this spreading being uniform between the distances corresponding (according to Struve's estimate) to the position of stars of magnitudes 1 to 6, of 7th magnitude, of 8th, and lastly of 9th magnitude. It seems impossible to attach the slightest weight to the evidence afforded by the resulting disc, since the construction of the disc is based on suppositions (as to the uniform scattering of stars radially towards the equator), which are directly contrary to Struve's own clear recognition of a want of uniformity circularly round the equator.

Struve deduced from this imperfect method of reasoning, combined with the study of Sir W. Herschel's star-gauges and a theory on the extinction of light, the conclusion that the Milky Way is unfathomable in its own level. He considered this view to be in accordance with the results obtained by Sir W. Herschel in his papers of 1817 and 1818. Herschel did not, however, find the Milky Way unfathomable all round the central line of the zone, but only in certain definite directions—towards the heart, in fact, of certain clustering aggregations. Struve misunderstood Herschel's remark that "when his gauges would no longer resolve the milky way into stars, it was not because its nature is ambiguous, but because it is fathomless," for he thus renders Herschel's words into French, "nous pouvons faire la conclusion que *si* nos jauges cessent de résondre la Voi Lactée en étoiles, ce n'est point parce que la nature en est douteuse, mais parce qu'elle est insondable." Doubtless he read Herschel's "when" as equivalent to the German "wenn."*

As Sir John Herschel has remarked, disposing thereby at once of Struve's infinite extension theory and of his reasoning respecting the extinction of light, "We are not at liberty to argue that at one part of the galaxy's circumference our view is limited as by a sort of cosmical veil, which extinguishes the smaller magnitudes, cuts off the nebulous light of distant masses, and closes our view in impenetrable darkness; while at another we are compelled by the clearest evidence telescopes can afford to believe that star-strewn vistas *lie open*, exhausting their powers and stretching out beyond their utmost reach, as is proved by that very phenomenon which the existence of such a veil would render impossible, viz., infinite increase of number and diminution of magnitude, terminating in complete irresolvable nebulosity." This reasoning is complete against Struve's inferences as based on Struve's assumptions. It is not, however, the less certain that irresolvable nebulosity does *not* necessarily imply that the objects producing it "stretch out beyond the utmost reach of the telescope," as is proved by the irresolvable nebulosity discovered by Sir John Herschel himself within the bounds of the Magellanic clouds.

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* Thus is explained what Sir John Herschel and Professor Nichol clearly found perplexing, viz., Struve's conviction that the elder Herschel's results confirmed his own remarkable theory.

I shall treat very briefly of the results to which I have been led by my own researches into the subject of the constitution of the heavens, because they have been fully presented elsewhere.*

The purposes I have had in view throughout my inquiries have been two—First, to proceed in perfect independence of all preconceived theories—to inquire how the stars and nebulæ are spread in space, how they differ in magnitude or constitution, and what laws govern their changes and movements, instead of adopting any assumptions on these points as bases for reasoning; and, secondly, to endeavour in every case to render palpable to the eye the relations which have hitherto been presented only in elaborate catalogues or in tables of statistics. It is to subserve the latter purpose, which is obviously associated most intimately with the former, that I have adopted the method of equal-surface charting. In dealing with the proper motions of the stars I have drawn from each star an arrow whose length and direction shall indicate the rate and direction of the star's proper motion. I venture to believe that by these and other contrivances I have been enabled to exhibit the above-mentioned relations altogether more intelligibly than has hitherto been the case, and that laws hitherto unrecognised have thus been brought to light.

In the first place, I have been able to show that the stars, down even to the sixth magnitude only, are markedly crowded upon the milky way, and that, moreover, there are two rich stellar regions (as respects these lucid stars), nearly opposite each other, one covering the constellations Cepheus, Cygnus, Cassiopeia, and Draco, the other occupying the space included between the heel of Argo, Crux, and the Greater Dog. The following table (shortened from one in my "Essays") indicates the numerical relations involved, the numbers in the second column representing the total number which would be visible if the whole heavens were as richly spread as the several regions indicated in the first column:—

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* I may be permitted to point out that the researches themselves, as originally submitted to the Royal Astronomical Society, are contained in my "Essays on Astronomy."

	Richness.
Northern Milky Way	9,940
" rich region	9,050
" poor region (equally large) .	2,567
Gaps in Milky Way	1,240
Southern poor region	2,361
" rich region (equally large) .	13,126
" Milky Way	13,596

It will be observed that the richness of the whole Milky Way would be represented by 11,768, *exceeding more than nine times* the number representing the distribution of stars over the gaps and lacunæ of the Milky Way.

By extending the process of charting to include all the 324,198 stars in Argelander's series of forty charts, even more decisive evidence is obtained of the absolute intermixture in space—*i.e.*, within certain definite clustering aggregations—of stars of the brighter orders and the telescopic stars studied by the Herschels. For in the very regions where the Herschelian gauges showed the minutest telescopic stars to be most crowded, my chart of 324,198 stars shows the stars of the higher orders (down only to the 11th magnitude) to be so crowded that by their mere aggregation in the mass they show the Milky Way with all its streams and clusterings. This evidence, I venture to affirm, is altogether decisive as to the main question, whether large and small stars are really intermixed in many regions of space, or whether the small stars are excessively remote. It is utterly impossible that excessively remote stars could seem to be clustered exactly where relatively near stars are richly spread. This might happen, no doubt, in a single instance, but that it could be repeated over and over again, so as to account for all the complicated features seen in my chart of 324,198 stars I maintain to be utterly incredible.

By applying the process of equal-surface charting to the nebulæ, I find that they are so arranged over the heavens as to leave no room for doubting their association with the sidereal system. Moreover, they are found to run into streams or branches, intimately associated with streams of stars. And strangely enough, as the great star-streams seen in Eridanus and Aquarius are prolonged so as to enclose the Magellanic Clouds, so the great southern nebular streams extend themselves to the same groups. The association of these streams of nebulæ and stars could scarcely be regarded as accidental; but the fact that both sets of streams converge upon those very regions where stars and nebulæ are so strangely intermingled removes all doubt from the conclusion that in the nebulæ (for these streams include all the known southern nebulæ) we have not to deal with external galaxies, but with objects belonging to the sidereal system.

The charting of the stellar proper motions has further led me to the discovery of the fact that the stars in many parts of the heavens are travelling in systems—or as it were drifting—through space. Thus the five stars, β, γ, δ, ε, and ζ, Ursæ Majoris, are found to be all moving together, as one grand scheme.* In Gemini there is a much more remarkable instance of drift, nearly all the stars of that constellation (Pollux is one of the exceptions) travelling in one general direction. In Taurus there is also well-marked drift. These instances of drift suffice to afford independent testimony in favour of the existence of systems subordinate to the great sidereal system.

The general conclusions to which I have been led by these and other methods of research, which space will not permit me to particularise further, are chiefly these:—The sidereal system is altogether more complicated, altogether more varied in structure, than has hitherto been supposed. Within one and the same region co-exist stars of many orders of real magnitude, the greatest being thousands of times larger than the least. All the nebulæ hitherto discovered, whether gaseous or stellar, irregular, planetary, ring-formed, or elliptic, exist within the limits of the sidereal system. They all form part and parcel of that wonderful system whose nearer and brighter parts constitute the glories of our nocturnal heavens.

It has been supposed that the new views to which I have been led would, if accepted, tend to reduce our estimate of the scale on which the universe is constructed. This, however, is not the case. It is true that I cannot recognise in the clustering regions of the Milky Way the profundities commonly believed in; but I believe in profundities far vaster. It is true that I believe the varieties of structure brought into view by higher and higher telescopic powers to be real and not apparent; but if I thus recognise the existence of stars much smaller than neighbouring orbs, it is because I recognise in the larger orbs suns which surpass our own thousands of times in volume; while this very variety enhances out conceptions of the wonders of the sidereal system. It is true, again, that I cannot recognise in the star-cloudlets the external galaxies spoken of in our text-books of astronomy, that I recognise parts of our sidereal system where hitherto the common opinion has been that outlying universes are in question; but I reason thus, because I have been led to the conclusion that our sidereal system is much more extensive than has hitherto been supposed. I do not draw the nebulæ inwards to the star-depths, but I extend the star-depths outwards until they include the nebulæ. According to my views, the range of our telescopes is neither greater nor less than has been hitherto supposed: if, then, I conceive that the sidereal system reaches to unknown depths beyond that range, it is not because I would reduce our estimate of the scale on which the sidereal system is constructed, but because I would enlarge that estimate, and that not by a little but indefinitely.

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* More than two years ago, speaking of this discovery, which I had then but recently made, I expressed my conviction that if ever Dr. Huggins was enabled to determine the proper motions of these stars in the line of sight, he would find them to be all travelling one way, either receding or approaching. Quite recently he has tested the matter, and he finds that not only have these five stars similar spectra unlike the spectra of α and η, but that whereas α is approaching, and η receding more slowly, the five are all receding at the rate of thirty miles per second.

A few last words on the wonderful scene presented by the star depths. Let us reflect on what we know about our own earth and its wonders, what seems to our conceptions its vast extent, and the activity that pervades its every portion, whether we consider life upon its surface or the physical forces at work in all parts of its gigantic globe. Regarding this orb on which we live as one among many which attend upon the sun, all speeding with inconceivable velocity around that glorious star, how wonderful becomes the thought that the dimensions of all the members of the solar system—nay of the sun himself, are reduced to utter insignificance, compared with the range of that system. Next let us dwell upon the thought that that whole system is travelling bodily through space with utterly inconceivable velocity; and that the region of space thus traversed by the solar family is so vast that the dimensions of the solar system are in turn dwarfed to utter insignificance. Then let us picture the scheme of suns of which our sun is a member; not the sidereal system, scarcely even an appreciable fraction of the sidereal system, but the particular family of suns to which the sun belongs; and let us consider how the domain of the sun, the region of space over which he holds sway,—a region so vast that millions of years would be required for him to gather in from its outermost parts the material over which his sway extends, is in *its* turn reduced to mere nothingness by comparison with the scheme of suns of which our sun is a member. Then lastly—so far as human researches are concerned, but by no means lastly in real truth—let us picture to ourselves that the scheme of stars to which our sun belongs is but one of the atoms, so to speak, of which the frame of the sidereal system is built. We can speak of these things, but who shall understand them: who shall form adequate conceptions respecting them? The astronomer can spread out the figures which represent these wonders, but there his power ceases; he can neither conceive them himself nor render them conceivable by others. I know not, then, how I can more fitly draw my subject to a conclusion than by quoting that wonderful dream in which the German poet presents the feebleness of human conceptions in the presence of the infinite wonders of the universe. It may, indeed, truly be said, that on the one hand astronomical discoveries have made this dream a reality, while on the other, if we accept as well what the poet's words suggest as what they actually present, they exhibit the truest picture which words can convey of that universe which nevertheless is unpicturable:—

"God called up from dreams a man into the vestibule of heaven, saying, 'Come thou hither, and see the glory of my house.' And to the servants that stood around his throne he said, 'Take him and remove from him his robes of flesh, cleanse his vision, and put a new breath into his nostrils: only touch not with any change his human heart, the heart that weeps and trembles.' It was done: and with a mighty angel for his guide, the man stood ready for his infinite voyage; and from the terraces of heaven, without sound or farewell, at once they sailed away into endless space. Sometimes with the solemn flight of angel wings they fled through Zaharas of darkness, through wildernesses of death, that divided the worlds of life; sometimes they swept over frontiers that were quickening under prophetic motions from God. Then, from a distance that is counted only in heaven, light dawned for a time through a shapeless film; by unutterable pace the light swept to them, they by unutterable pace to the light. In a moment the rushing of planets was upon them; in a moment the blazing of suns was around them.

"Then came eternities of twilight that revealed but were not revealed. On the right hand and on the left towered mighty constellations, that by self-repetitions and answers from afar, that by counterpositions built up triumphal gates, whose architraves, whose archways, horizontal, upright, rested, rose, at altitude, by spans, that seemed ghostly from infinitude. Without measure were the architraves, past number were the archways, beyond memory the gates. Within were stairs that scaled the eternities around; above was below, and below was above, to the man stripped of gravitating body; depth was swallowed up in height insurmountable, height was swallowed up in depth unfathomable. Suddenly, as thus they rode from infinite to infinite, suddenly as thus they tilted over abysmal worlds, a mighty cry arose, that systems more mysterious, that worlds more billowy, other heights and other depths, were coming, were nearing, were at hand.

"Then the man sighed and stopped, shuddered and wept. His overladen heart uttered itself in tears; and he said, 'Angel, I will go no farther; for the spirit of man acheth with this infinity. Insufferable is the glory of God. Let me lie down in the grave, and hide me from the persecution of the infinite, for end I see there is none. And from all the listening stars that shone around issued a choral voice, 'The man speaks truly: end there is none that ever yet we heard of!' 'End is there none?' the angel solemnly demanded: 'Is there indeed no end? And is this the sorrow that kills you?' But no voice answered, that he might answer himself. Then the angel threw up his glorious hands to the heaven of heavens saying, 'End is there none to the universe of God? Lo! also there is no beginning.'"

IV. MEDIÆVAL AND MODERN ORDNANCE AND PROJECTILES COMPARED.*

By Capt. S. P. Oliver, Royal Artillery.

THANKS to the deep researches of Major-General Lefroy (now Governor of Bermuda), Captain H. Brackenbury, and others, the history of European and foreign ordnance, from its hazy origin in the middle ages down to modern times, is tolerably familiar to all military and naval artillerists through the medium more especially of the periodical publications of the Royal Artillery Institution at Woolwich.

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* I. "On Two Large English Cannon of the Fifteenth Century, preserved at Mont S. Michel, in Normandy." By Brigadier-General Lefroy, R.A., F.R.S. —"Proc. Roy. Art. Institution, Woolwich," vol. iv., No. 1, 1864.
II. "Mons Meg, the Ancient Bombard, preserved at Edinburgh Castle." By J. Hewitt, Esq., War Office.—"Journal of Archæological Institute," No. 37.

On the contrary, however well up (thanks to the daily press) in the size, weight, and power of contemporary cannon, and in the velocity and penetration of elongated projectiles, &c., the public are too apt to regard with contempt what they consider the puny prototypes of our present magnificent guns; and perhaps would be surprised to learn that the cannon and missiles, both European and Oriental, whilst the art of their construction was yet rude and still in its infancy, attained a size and weight equal to, if not exceeding, our largest and latest pieces and projectiles.

The Orientals were far in advance of the Europeans in their acquaintance with metallurgy, and there is good authority for supposing that bronze was known to them at a remote age, and, according to Fergusson, "the Indians were as familiar with the use of iron in the fourth century B.C., as the Greeks themselves were, and for anything we know to the contrary, may have understood the art of extracting it from the ore and using it for arms and cutting tools before these arts were practised in Europe" ("Rude Stone Monuments," p. 480). Indeed, it is not impossible that bullets were used in Asia when our ancestors were not beyond flint arrow-heads; at all events it seems certain that gunpowder was used in India and China before the Christian era. We are apt to take a certain pride in our forgings when we read of iron bars 270 feet* in length being coiled on a mandril to form the coil of a gun in the nineteenth century A.D.; but Mr. Fergusson rather takes the conceit out of us when he informs us of the existence of an iron pillar in the courtyard of a mosque near Delhi, consisting of a solid shaft of wrought-iron standing 22 feet 6 inches out of the ground, and 26 feet deep in the ground, that is nearly 50 feet in total length, and 5 feet 6 inches in circumference. Mr. Fergusson adds that such a single

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III. "Ancient Cannon in Europe." By Lieut. H. BRACKENBURY, R.A.—"Proc. Roy. Art. Institution, Woolwich," vol. iv., No. 10, 1865, *et. seq.*

IV. "An Account of the Great Cannon of Muhammad II., recently presented to Her Majesty by the Sultan, with notices of other great Oriental Cannon." By Brigadier-General LEFROY, R.A., F.R.S.—"Proc. Roy. Art. Institution," vol vi., No. 6, 1868.

V. "Notice of a Stone Cannon Ball Dredged up in Falmouth Harbour, and of the use of Stone Shot." By Sir Charles LEMON, Bart., M.P., F.R.S.—"Twenty-sixth Annual Report of the Royal Institution of Cornwall." Truro, 1845.

* The bar of iron to form coil for new 36-ton gun will be 1200 feet in length.

forging "could not have been made in Europe before the introduction of steam machinery, nor, indeed, before the invention of the Nasmyth hammer." There is an inscription on the pillar which leaves no doubt that the pillar must have have been erected in the third or fourth century of our era. Mr. Fergusson leaves it "to those practically skilled in the working of metals to explain how any human being could work in close proximity to such a mass heated to a welded heat, or how it was possible without steam machinery to manipulate so enormous a bar of iron." If Mr. Fergusson considers that it was necessary to heat at one time the *whole* pillar to a *white* heat it was doubtless a difficult task to manipulate it, although a man need not be a human salamander to approach it closely; and when cooled to the *cherry-red* heat requisite for forging it could easily be approached without inconvenience. But in all probability this pillar was built up, being formed in lengths placed from opposite sides in the furnace, and welded under a huge stone or metal hammer, which was probably lifted and dropped after the style of a pile-driving monkey. Indeed among the Chinese there is in use (and among the Chinese that means also has been in use for the last thousand years) a hammer or stamper not dissimilar to the "*Schwartz hammer*" or "belly-helve" of modern days. A colossal hammer of this description could readily be erected and used by artificers unacquainted with steam machinery.*

The earliest authentic record of the existence of cannon in Europe is found in a document dated 11th February, 1326 A.D., and fifty years afterwards we read of cannon throwing projectiles of 200 lbs. weight at the seige of Odruik, and a contemporary chronicle also gives an account of a 450-pounder gun being used by the Duke of Burgundy in 1377, the diameter of whose bore must have been at least 21 inches. In Italy, however, the manufacture of cannon developed most rapidly. Capt. H. Brackenbury gives an interesting account of the performances of two huge Venetian bombards in 1380 at Brondolo. One named the "*Trivisana*" was a 295-pounder, and the other, the "*Veneziana*," was a 145-pounder. "Pisani established these guns in battery on the bank, and proceeded to bombard Brondolo. On the 22nd January the great bombard was fired, and it struck the Campanile of Brondolo, knocking down a great piece of the wall, the stones of which struck and killed the Genoese general and his nephew. On the 23rd the same bombard knocked down a great piece of the wall of the same Campanile and killed twenty-two men. Capt. Brackenbury, after tracing the history of cannon through the second half of the fourteenth century, states in the following few pertinent words the conclusions to which he is led:—"Cannon of iron and bronze under the various names of *guns*, *bombards*, *cannon*, *sclopi* or *schioppi*, are found bound down to large heavy wooden beds, and employed in sieges both for attack and defence throughout the whole period. Projectiles of lead, stone, and, in Italy, iron, and even bronze were thrown by them; also arrows and Greek fire. But it appears from the length of time which sieges lasted that the art of opening a practicable breach by means of cannon had not yet been invented. Indeed it is very doubtful whether with such powder sufficient force could have been obtained for that purpose. This powder was still a comparatively feeble agent; the ingredients pounded by hand in a mortar were themselves but imperfectly purified, and when reduced to a state of fine powder the gas must have passed very slowly through the mixture, and an immense quantity of the charge must have been blown out without being ignited. To prevent excessive windage the leaden shot were driven forcibly home into the bore of the piece by means of a mallet and drift, and the soft nature of the metal allowed them completely to fill the bore. With iron and stone shot fired from the large guns no drift was used, but the shot was inserted from the muzzle and the powder by a scoop from the breech, which was then closed by a wooden tompion; the hot iron was still used to fire the charge through a vent, which was often covered to keep the powder dry. But rough as these appliances were *we must not despise too much the cannon of the fourteenth century*. They were suited to the age. To knock down such a piece of wall as to kill twenty-two men at once is a feat which is not easy even in these days."

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* Capt. C. B. Brackenbury, R.A., describes the endurance of the men at Mr. Krupp's Essen establishment as being severely tested when large steel castings are made. He says, "It has occurred that some of them have shaken their heads about undergoing so terrible an "*ordeal by fire*" during hot weather, but the energy of Mr. Krupp has carried all before him, and by extra pay for heavy work, and exciting their undoubted *esprit de corps*, they have been brought to face anything, although many of them have fainted under the trial when large castings have necessarily been made in hot weather."—*Vide* Report of a Professional Tour of Officers of the Royal Artillery under Col. A. C. Pigou, R.A., 1865, p. 116.

Fortunately for military archæologists, there are in existence good examples of early ordnance whose date is well established; the oldest known being two English guns abandoned at the siege of St. Michel, Normandy, at the end of October, 1423, and which now remain in front of the

Plate I.

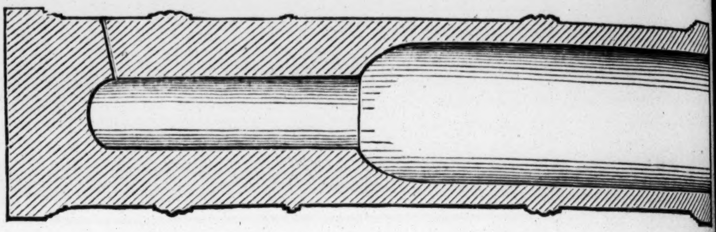
I.

TZAR-POOSCHKA.

THE GREAT GUN OF MOSCOW.

Cast A.D. 1586.

Diameter of bore, 36 in.; diameter of chamber, 19 in.; length of bore, 122 in.; length of chamber, 70 in.; total exterior length, 210 in.; weight, 38·5 tons.

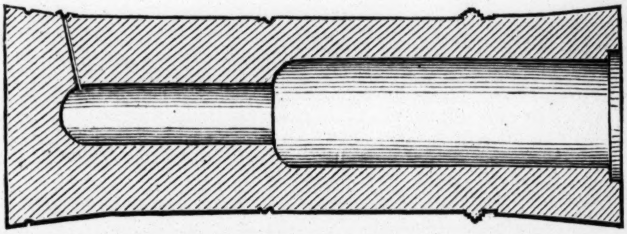


II.

GREAT GUN OF BEEJAPOOR.

THE MALIK-I-MYDAN, OR MASTER OF THE FIELD.

Cast A.D. 1548.

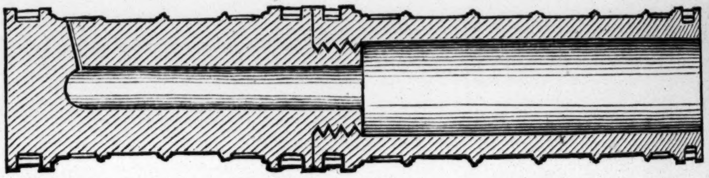


III.

CANNON OF MUHAMMAD II.

(*A.D.* 1464).

Length, 17 ft.; diameter of powder chamber, 10 in.; diameter of bore, 25 in.; weight, 18 tons 14 cwts. 3 qrs. The stone shot weigh 670 lbs.



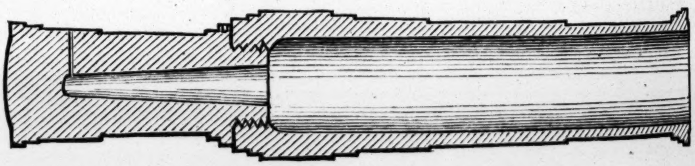
IV.

THE DULLE GRIETE.

WROUGHT-IRON GUN AT GHENT.

Probable Date A.D. 1430.

From measurements by Professor W. Pole, F.R.S., September, 1864.



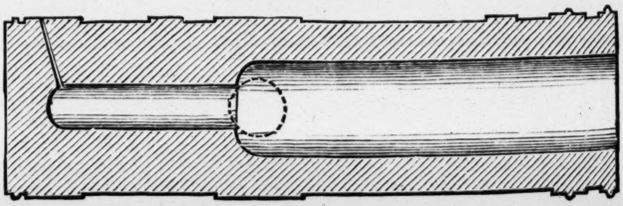
V.

GREAT GUN OF AGRA.

DHOOL DHANEE.

Cast A.D. 1628. *Broken up and sold for the metal*, 1832.

From a drawing by Captain J. F. Boileau, Bengal Engineers, April 28, 1832.

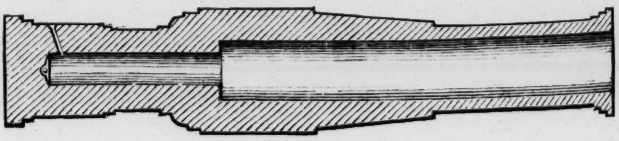


VI.

MONS MEG.

A.D. 1460.

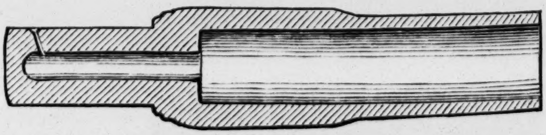
EDINBURGH.



VII.

MICHELETTE.

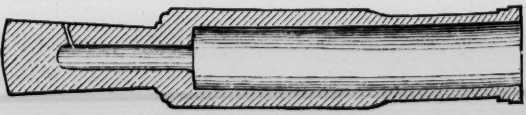
LA GRANDE.



VIII.

MICHELETTE.

LA PETITE.



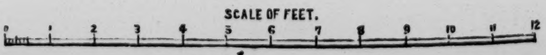
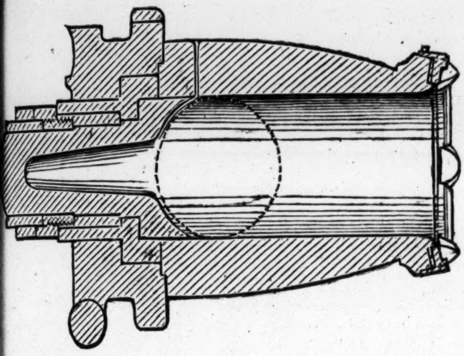


Plate II.

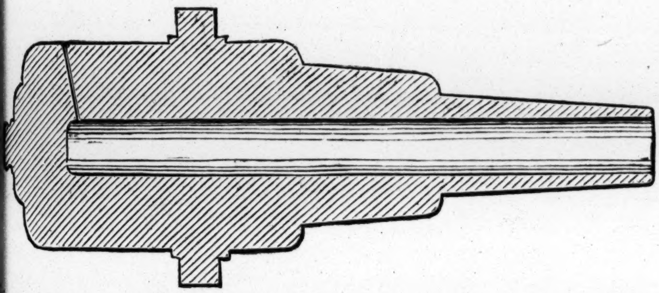


I.

MALLET'S 36-INCH MORTAR,

OF 42 TONS.

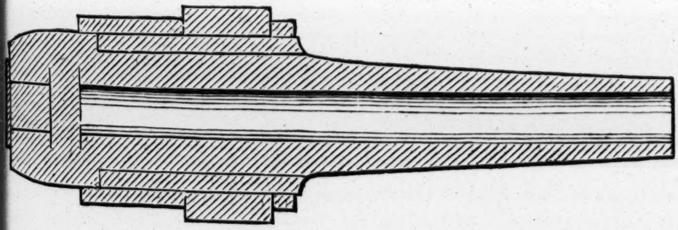
Tried at Woolwich, 1857-8.



II.

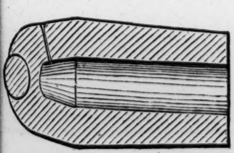
12-INCH WROUGHT-IRON MUZZLE-LOADING GUN, 35 TONS.

Rifling:—No. of grooves, 9; depth of groove, 0·2″; width, 1·5 (*i.e.*, same as 10-inch); twist, from 0 to 1 in 35 cals.



III.

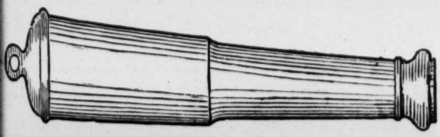
KRUPP'S 11-INCH PRUSSIAN BREECH-LOADING GUN.



IV.

13-INCH SEA-SERVICE MORTAR.

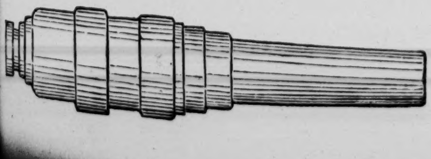
Weight, 100 cwts.



V.

68-POUNDER.

95 cwts.



VI.

ARMSTRONG.

7-INCH BREECH LOADER.

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second gateway of the fortress on Mont St. Michel. Professor Pole took great trouble in measuring these guns and the granite cannon balls he found within them in 1863. He estimates the weight of the larger gun at about 5⅓ tons, and that of the smaller at 3¼ tons. He says the largest gun is 19 inches in calibre, and 12 feet in total length, of which the chamber composes more than one-fourth; the granite balls are about 18 inches in diameter; the smaller gun is 15 inches in calibre, and 11 feet 9 inches in total length. The construction of the barrels is clearly visible; they are formed of wrought-iron, being made up of longitudinal bars, each about 2¾ inches wide by 1 inch thick, and round the outside are seen the lines of hoops, each about 2¾ inches wide placed quite close to each other. It is not possible to discover whether the hooping is single or in several layers.

The exterior of the breech or powder chamber consists not of hoops but of *longitudinal bars*, their flat surfaces giving to it the section of a polygon. The next gun in point of age is the far-famed "Dulle Griete," the great bombard of Ghent, which dates about 1430. This enormous wrought-iron piece is calculated to weigh 13 tons, and has a bore of 25 inches in diameter. Professor Pole estimates the weight of the granite ball, 24 inches in diameter, to be about 700 lbs. The next on General Lefroy's list is that "*mickle-mouthed murtherer*," Mons Meg,* the ancient bombard preserved at Edinburgh Castle, which is supposed to have been built previous to 1460. She weighs 5 tons, and the diameter of her bore, according to Lieut. Bingham's† drawing, is 20 inches. Mr. Hewitt mentions the mode of construction of this Scottish gun as being plainly shown at the point where it has been "*riven*." Longitudinal strips of iron are ranged like the staves of a cask and welded together; and then a number of rings or hoops, also of wrought-iron, are driven tightly over them. The thickness of the bars is 2½ inches; that of the hoops 3½ inches. There is no core beneath the strips, as in some of the early bar and hoop guns; but the welded staves themselves form the cylinder. The magnitude of this engine, the contrivance of its parts, and the nice proportions of its outline, show that it is by no means one of the earliest efforts of the gunsmith's art." "The name of Mons borne by this bombard is generally attributed to its having been fabricated at the town of that name in Flanders; and the probability seems to gather strength from the circumstance of the great gun of Ghent resembling it so closely in model and construction. These mediæval wrought-iron bar and hoop guns were manufactured up to the middle of the sixteenth century; and there are yet in existence in the Tower and in the Repository at Woolwich some very perfect specimens, which, together with brass cannon, were recovered by Mr. John Deane in the summer of 1840 from the wreck of the "Mary Rose" at Spithead, which "goodlie shippe of England was by too much folly drowned in the middest of the haven; for she was laden with much ordinance, and the portes left open, which were very lowe, and the great ordinance unbreached; so that when the shippe should turne the waters entered, and so dainly she sank." This occurred during the reign of Henry VIII., in 1545, the very year in which cast-iron cannon were first made in England. One of the guns is in an excellent state of preservation, considering it to have been immersed for 300 years: it is composed of a tube of iron, whose joint or overlap is as its length; upon this is a succession of iron hoops composed of iron 3 inches square; these appear to have been driven on whilst red-hot. It has a movable breech chamber, and is let into a solid block of elm, hollowed out to allow of the breech-piece being drawn back for loading, a wooden chock and iron wedge being used to keep the chamber in position when forced home. Both the brass cannon (then a new invention according to Grose, who dates the first founding of brass cannon in England as 1537), and these hoop and bar guns were found loaded, the brass guns with iron shot, and the iron guns with stone shot. Stone shot appear to have been common up to this period, as we learn in Rymer's *Fœdera* of two hundred stone shot being made in the Folkestone limestone quarries as early as the 17th year of Edward III., 1334; and in the same author is an order of Henry V. to a mason of Maidstone to provide 7000 stone shot from the quarries there, which, like the Folkestone beds, consists also of the lower greensand limestone formation, and, besides, several ancient cannon shot have been found there in the *débris* of the old workings. We cannot leave this portion of the subject without regretting that Captain Brackenbury has not yet been able to carry on his history of the ancient cannon in Europe beyond the date of 1400, since February, 1866. The Artillery Institution has looked for Part III. on the ordnance of the fifteenth century, which is not yet forthcoming. We must hope that the

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* Mons Meg was brought into action at the siege of Dumbarton, 1489, and at Norham, 1497, in the reign of James IV. of Scotland, and Henry VII. of England.

† The late Col. Charles Bingham, R.A., Deputy Adjutant-General, Royal Artillery.

Professor of Military History at the Royal Military Academy will find leisure to publish a continuation of his interesting history.

We will now turn the attention of the reader to the Oriental cannon, and it should be noticed that General Lefroy points out how these Indian and Russian ordnance were in all probability copied from Flemish originals. Comparing the gun of Muhammad II., presented by the Sultan to the Queen in 1868, and now at Woolwich, with the Ghent Bombard, the General finds the dimensions, allowing for the necessary difference between wrought-iron and bronze, to correspond more closely than can be attributable to accident, and this correspondence extends to the method of construction in both cases, the powder-chamber being a separate forging or casting, and screwed to the body.

In proof of the family resemblance of all the great bombards which is so apparent on comparing drawings made to the same scale, General Lefroy subjoins the following table of their principal dimensions :—

LIST OF GREAT BOMBARDS NOW OR LATELY EXTANT.

Nature.	Date.	Weight in tons.	Diameter.			Length.		
			Bore.	Chamber.	Exterior.	Bore.	Chamber.	Over All.
WROUGHT-IRON :—			″	″	″	″	″	″
English guns now at Mont S. Michel .. *A*	Before 1423	5·3	19·0	5·75	30·0	94·0	48·0	197·0
B		3·3	15·0	5·01	22·0	80·0	36·0	156·0
Dulle Griete, Bombard of Ghent	After 1430	13·0	25·0	10·00 6·00	39·0	1272·0	56·0	197·0
Mons Meg, Edinburgh ..	Before 1460	5·7	20·0	10·00	29·5	106·0	45·0	159·0
BRONZE :—								
Cannon of Muhammad II., Woolwich	1464	18·7	25·0	10·00	41·5	110·2	75·8	204·7
Malik-I-Mydan, great Gun of Beejapore	1548	40·0	28·5	16·00	57·0	93·0	60·5	170·6
Tzar Pooschka, great Gun of Moscow	1586	38·5	36·0	19·00	63·0	122·0	70·0	213·0
Dhool Dhanee, great Gun of Agra	1628	30·2	23·2	10·05	45·5	108·0	50·0	170·2

The hugest piece of ordnance ever known to have existed was a celebrated cast-bronze piece at Agra, named the Zufr Bukh, Giver of Victory, which weighed fifty-two tons, according to the account extracted by Major-General Boileau, R.E., from a pamphlet in the Hindoostanee language, by which the date of its fabrication appears to be anterior to A.H. 1037, *i.e.* A.D. 1627. What has become of this gun does not appear. Next in importance is the renowned great gun of Beejapore, Malik-i-Mydan, or Lord of the Plain, forty tons in weight, cast at Ahmednugger in the reign of Boorhan Nizan Shah I., A.H. 956 or A.D. 1548, under the superintendence of the General of Artillery, Muhammad Vin Hassan Roumi, that is, of Constantinople. Notwithstanding its great weight, Colonel Meadows Taylor considers that this gigantic cannon could be brought to Bombay, *viâ* Sholapore, whence it could easily be transported to the Repository at Woolwich. General Lefroy says:—

"The superstition of the Hindoos long ago converted this gigantic cannon into an object of worship, and they might be seen placing offerings of flowers and copper coins within the muzzle. It is believed to have been last fired on the occasion of a visit of the Rajah of Sattara to Beejapore in the last century, and the people gravely assert that it caused all the pregnant women within hearing to miscarry. The charge was 80 lbs. of powder. The shot, of which several remain, are made of fine hard basalt, and weigh about 1000 lbs. It is mentioned in the "Journal of the Royal Asiatic Society of Bengal" (Vol. I), that an Italian who served in the Mogul armies under the title of Rumi Khan, had this gun in his park of artillery, and used it in several battles, occasionally firing sacks of copper coins out of it."

The Dhool Dhanee, "The Disperser or Scatterer," or great gun of Agra, cast in 1628, was broken up and the material sold for over £3000 in 1832; fortunately Major-General Boileau took careful measurements of it before its economical and ignoble destruction. That these huge pieces were by no means uncommon appears from the fact, that the Malik-i-Mydan was one of 701 cannon abandoned in the disastrous retreat from Kulliani, A.D. 1562. Many other fine specimens of Indian guns, such as the large Bhurtpoor cannon at Woolwich, cast as late as 1677, might be quoted to show the remarkable skill in metallurgical art possessed by the Asiatic races, in which the Chinese and Japanese were not behindhand. Perhaps the most remarkable gun, being the largest in calibre, viz. 36 inches, ever cast, is the work of the gunmaker Andrea Ichowhow, of Moscow, A.D. 1586, called the Tzar Pooshka, weight 38 tons. The outline of this gun (Plate 1) is reduced from Plate 5, copied from a drawing obtained by General Lefroy from Major-General de Novitzky, Aide-de-camp to the Emperor of Russia.

We now come to the great cannon of the Dardanelles, which "have been a subject of wonder to travellers and of interest to artillerymen from the earliest period. There are no other examples of guns which have remained in use for four centuries, and are still in a very real sense effective pieces of ordnance. They testify to the former energy and power of the Ottoman race as no other military monument does, and remind us of an event which has had a greater influence on the politics of Europe than almost any other within the same period—the fall of Constantinople. Monuments of the military genius of Muhammad II., they remind us also of "the splendour and the havoc of the East," by their prodigious size and cost and power. They form a class apart, and although there is reason to think that they are referable to a Flemish original, they bear the stamp of a national character and of an epoch of conquest of which European history presents scarce any other example." These guns were formerly very numerous, there being between forty to fifty of them at least. According to Mr. Wrench, H.M. Vice Consul, there were extant—twenty-one in 1868, three of which were since broken up, and two others sentenced to the same end; so excluding the one presented to Her Majesty there now remain fifteen: ten of these, comprising the largest (29·5 inches calibre), are in the Fort Kilit Bahar, on the European side of the Dardanelles, and the remaining five in the Sultanieh Fort of Chanak Ckalessi, on the Asiatic side of the straits. The Kilit Bahar guns average 25·25 inches calibre, the smallest bore being 19·5, and the Chanak guns 23·6 inches; the date of their construction extends from A.D. 1458 to 1521. General Lefroy surmises that those guns dated 1521 may possibly have been cast on the island of Rhodes for the subjection of that fortress, which fell December 22nd, 1522; and there is all the more reason for supposing this to have been the case, when we consider the Turkish habit of casting great ordnance on the spot where they were wanted with extraordinary energy and readiness. Thus, "in the first siege of Rhodes, 1480, Muhammad caused sixteen great pieces to be cast, called basilisks or double cannon, 18 feet long, and carrying a ball of 2 or 3 feet diameter; and here also we are told that their mortars "threw stones of a prodigious size, which flying through the air by the force of powder fell into the city, and lighting upon houses broke through the roofs, made their way through several stories, and crushed to pieces all that they fell upon; nobody was safe from them, and it was this kind of attack that gave the greatest terror to the Rhodians.

General Lefroy refers to the singularity of these guns three or four centuries old taking part in modern engagements, as in the memorable instance afforded in the passage of the Dardanelles by Sir John Duckworth's squadron, on March, 1807.*

The Dardanelles proper, it must be remembered, is where the channel is narrowed to little more than three quarters of a mile. On each side of this narrow strait stands a castle mounted with these heavy cannon. They are called the inner castles of Europe and Asia, or the castles of Sestos and Abydos; so it will be noticed that these guns could easily fire across the strait as Bishop Pococke, writing about 1740 quaintly observes, "they fire likewise with ball in answer to any ship that salutes the castle, as this does much damage where they fall, so the lands directly opposite pay no rent. James† in his naval history gives the following account:—"It was at 7 a.m. on the 19th February, 1807, that Sir John Duckworth's squadron weighed and steered for the entrance of the Dardanelles. The British ships then formed themselves in line of battle in the following order:—*Canopus*, *Repulse*, *Royal George*, *Windsor Castle*, *Standard*, having in tow the *Meteor*, *Pompée*, *Thunderer*, having in tow the *Lucifer*, *Endymion*, *Active*. At 8 a.m. the *Canopus* arrived abreast of the outer castle, both of which opened fire upon her. At 9.30 a.m. the leading ship of the British squadron arrived abreast of the inner pair of castles which also opened fire within point-blank shot; this fire was returned by the ships of the squadron in succession as they passed, and doubtless with some effect. The damage sustained by the British ships in passing the Dardanelles, for that object had now been attained, was comparatively trifling." Not a mast or yard had been shot away, but only a few spars injured. The total—six killed and twenty-one wounded." Then follows the account of the destruction of the Turkish squadron, which was burnt and blown up as it lay beyond Abydos, whilst Lieutenant Nichols, R.N., with Lieutenant Finmore of the Marines, and party, landed and took by assault a redoubt, from which the Turks fled at their approach; he then set fire to the gabions and spiked the guns, eight of which were of brass, and carried *immensely large marble balls.*

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* Baron de Tott relates how he saw one of these pieces loaded with 330 lbs. of powder and discharged. He observed the shot break into three pieces at 600 yards from the gun, and these pieces crossed the Dardanelles, leaving the surface in a foam where they struck, and went bounding up the opposite shore.

† "Naval History of Great Britain, from the Declaration of War by France in 1793, to the Accession of George IV." By William James. New Edition. Bentley, 1860. Vol. iv., p. 209 *et seq.*

It was in repassing or rather escaping through the Dardanelles on the 3rd of March following, that Sir John Duckworth's vessels suffered such discomfiture from the stone shot. The ships then proceeded down the channel in nearly the same order in which they had sailed up. Hoping to propitiate the Turks Sir John fired a salute of thirteen guns, this produced an immediate return of shot and shell from the two castles, and from the battery on Point Pesquies. The other batteries on both sides, successively as the ships arrived abreast of them, opened their fire, and received a fire in return. The mutual cannonade was kept up until nearly noon, when the British squadron anchored off Cape Janizary, out of the reach of further molestation.

The following is the detail showing the damage caused by the stone shot:—"The *Canopus* had her wheel carried away and her hull much damaged by the stone shot, but escaped with the loss of only three seamen wounded. On board the *Repulse*, a stone shot from the castle on the Asiatic side came through between the poop and the quarter-deck, and killed two quartermasters, five seamen, and three marines, and wounded one lieutenant of marines, two corporals, and five privates, also two quartermasters and a boatswain's mate: total, ten killed and ten wounded, the only loss which the *Repulse* on this occasion sustained. The same shot badly wounded the mizen mast, broke and carried away the wheel, and did other serious damage. The *Royal George* had several lower shrouds cut away, her masts slightly wounded; a large stone shot also stuck fast in her cutwater. Her loss amounted to two seamen and one marine killed, two officers, one petty officer, twenty-two seamen, and two marines wounded: total, three killed and twenty-seven wounded.

"A stone shot of 800 lbs. weight struck the mainmast of the *Windsor Castle* and cut it more than three quarters through; her loss amounted to three seamen killed, one petty officer and twelve seamen wounded. On board the *Standard*, a stone shot from the castle of Sestos, weighing 770 lbs., and measuring 6 feet 8 inches in circumference, and 2 feet 2 inches in diameter, entered the lower deck, killed four seamen, and having set fire to the salt boxes which were on the deck for immediate use, caused an explosion, that badly wounded one lieutenant, three petty officers, thirty-seven seamen, and six marines; the alarm of fire that followed the explosion caused four seamen to leap overboard, all of whom were drowned, making the *Standard's* total loss by this single shot (and which was all she sustained) amount to eight killed and drowned, and forty-seven wounded. The *Pompée* had the good fortune to escape without being struck by a shot in hull, masts, rigging, or sails. The *Thunderer*, on the other hand, was a good deal damaged, and had two seamen killed, and one lieutenant, one midshipman, ten seamen, and two marines wounded. The *Lucifer* had no one hurt. The *Active* received a granite shot weighing 800 lbs.,* and measuring 6 feet 6 inches in circumference, which passed through her side 2 feet above the water, and lodged on the arlop deck close to the magazine scuttle, without injuring a man. The aperture made by it was so wide that Captain Mowbray, on looking over the side to ascertain what damage it had done, saw two of his crew thrusting their heads through at the same moment. Had there been a necessity for hauling to the wind on the opposite tack she must have gone down."

Such was the last appearance, in European waters at least, of huge stone cannon-shot during action, and if they did as much execution in proportion during the siege of Scutari, from June 22nd to the 21st July, 1478, inclusive, a period of thirty days, they must have caused tremendous destruction. At first there were two guns only placed in battery against the place, which were gradually increased to eleven towards the end of the siege; these guns varied in calibre from 19·8 inches to 32·4 inches, and their weight from 373 lbs. to 1640 lbs. Each gun fired on an average 16 shots a day, giving a total of 2534 rounds. The weight of such a number of stone shot, which must have weighed at least 1000 tons, leads General Lefroy to suppose that these were cut on the spot, being dressed into spherical form from blocks in neighbouring quarries by slave labour. The relative sizes of these shot are shown in the diagram. We will hope that our ironclad fleet of the present day would not have to retreat after the fashion of Sir John Duckworth's squadron, although by this time 10-inch elongated projectiles have probably replaced the stone shot in the Dardanelles.

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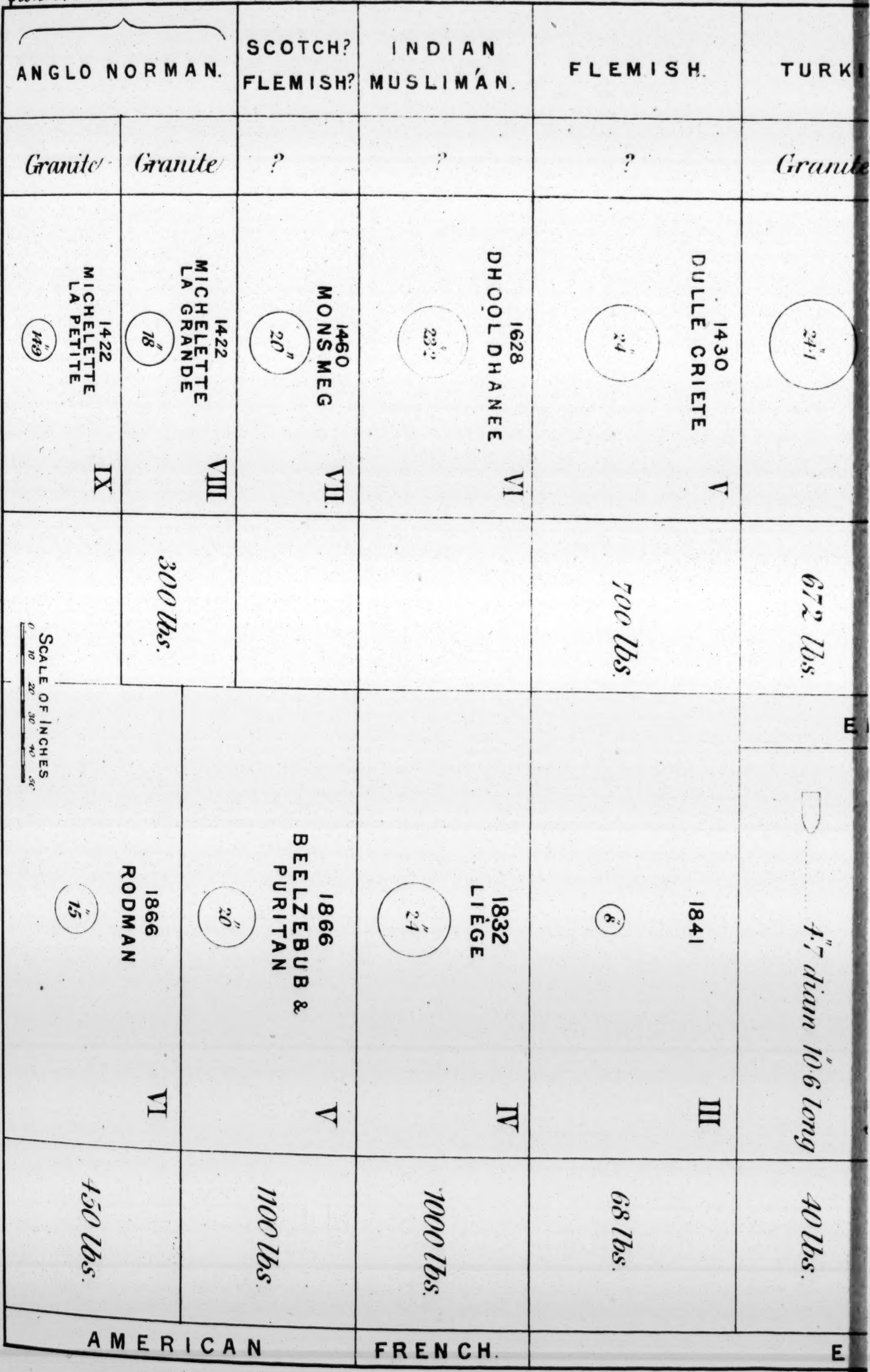
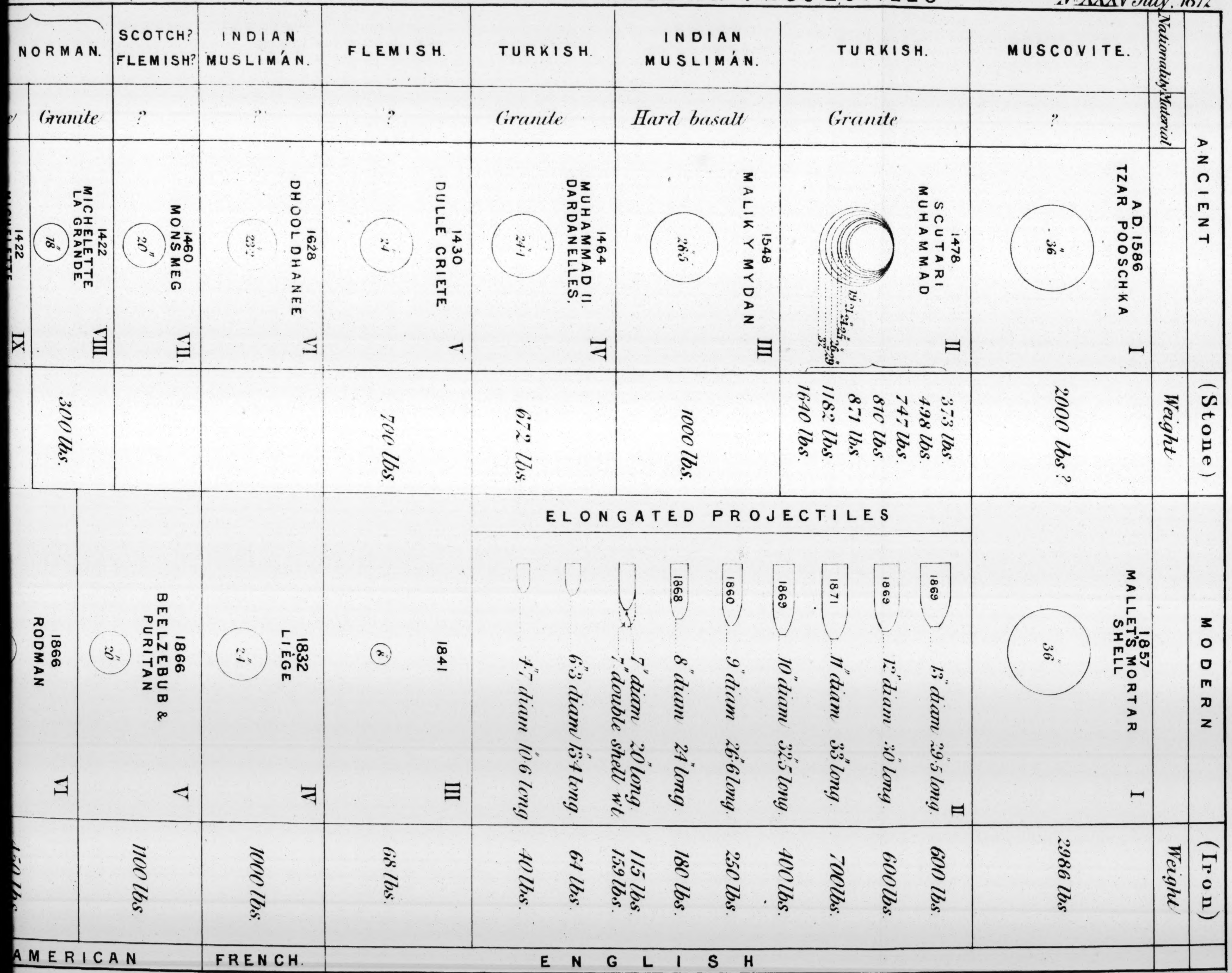
* General Lefroy considers the weight of the last shot exaggerated, and suggests that the boatswain put his foot into the scale, as a ball 78 inches in circumference will be under 25 inches in diameter, and not weigh more than 760 pounds. Some of these stone shot are at the Tower, others in the gun wharf at Portsmouth, at Sir John Duckworth's seat in Devonshire, and one at Admiral Tucker's, Trematon Castle, Cornwall.

RELATIVE SIZE OF ANCIENT



Vincent Brooks Day & Son Lith

RELATIVE SIZE OF ANCIENT & MODERN PROJECTILES



ANCIENT (Stone)

Nationality	Material	No.	Date and name	Diameter	Weight
MUSCOVITE.	?	I	A.D. 1586 TZAR POOSCHKA	36"	2000 lbs ?
TURKISH.	Granite	II	1478 SCUTARI MUHAMMAD	19" 21" 24" 25" 26" 29" 32"	373 lbs. 498 lbs. 747 lbs. 810 lbs. 871 lbs. 1182 lbs. 1640 lbs.
INDIAN MUSLIMÁN.	Hard basalt	III	1548 MALIK Y MYDAN	28·5"	1000 lbs.
TURKISH.	Granite	IV	1464 MUHAMMAD II. DARDANELLES.	24·1"	672 lbs.
FLEMISH.	?	V	1430 DULLE CRIETE	24"	700 lbs.
INDIAN MUSLIMÁN.	?	VI	1628 DHOOL DHANEE	22"	
SCOTCH? FLEMISH?	?	VII	1460 MONS MEG	20"	
NORMAN.	Granite	VIII	1422 MICHELETTE LA GRANDE	18"	300 lbs.
NORMAN.		IX	1422		

MODERN (Iron)

Nationality	No.	Date and name	Size	Weight
ENGLISH	I	1857 MALLET'S MORTAR SHELL	36"	2986 lbs
ENGLISH	II	ELONGATED PROJECTILES 1869	13" diam 29·5" long.	600 lbs.
		1869	12" diam 30" long.	600 lbs.
		1871	11" diam 33" long.	700 lbs.
		1869	10" diam 32·5" long.	400 lbs.
		1860	9" diam 26·6" long.	250 lbs.
		1868	8" diam 24" long.	180 lbs.
			7" diam 20" long. 7" double shell wt.	115 lbs. 159 lbs.
			6·3" diam 15·4" long.	64 lbs.
			4·7" diam 10·6 long.	40 lbs.
ENGLISH	III	1841	8"	68 lbs.
FRENCH.	IV	1832 LIÈGE	24"	1000 lbs.
AMERICAN	V	1866 BEELZEBUB & PURITAN	20"	1100 lbs.
AMERICAN	VI	1866 RODMAN		450 lbs.

Having thus briefly glanced at the ordnance of Mediæval times, and followed its characteristics as far as the time of the Tudors, we may here notice that ever since that period the architecture of artillery has been almost at a stand still; and the accompanying table of the time of Charles I. will give a good idea of the size of British Service Ordnance and Ammunition in use during the seventeenth century; and we know that those of the eighteenth century were not far different until 1779-80, the period when systematic improvements commenced in the manufacture of carronades, followed by General Blomefield's long naval pattern guns, Congreves, Dickson's, Millar's, Monk's, and Dundas's, the latest guns cast in the service.

Extracted by Colonel Clark, R.A., F.R.S., from "The Complete Souldier." Auctore Thomas Smith, 1628.

The Names of the Great Ordnance now used.	Height of diameter of each piece, in inches and parts.	Height of the bullet in inches and parts.	Weight of the shot in lbs. and parts.	Compass of the shot in inches and parts.	Weight of corne powder to charge each piece in lbs. and parts.	Weight of the piece in lbs. about.	Length of the piece in feet about.
Cannon	8	7¼	64	25 1/7	32	8000	12
Cannon Serpentine ..	7½	7¼	52	23 4/7	26	7000	11½
French Cannon	7¼	7	46¾	22 11/14	23¼	6500	12
Demi-Cannon eldest..	6¾	6½	36⅝	21 3/14	20	6000	11¼
Demi-Cannon ordinary	6½	6¼	32	20 3/7	18	5600	10½
Demi-Cannon	6	5¾	24½	18 6/7	16	5000	11
Culvering	5½	5¼	19	17 2/7	15	4600	13¼
Ordinary Culvering ..	5¼	5	16¼	16½	12½	4300	12
Demi-Culvering ..	4½	4¼	11¾	14 1/7	9	3000	11
" something less..	4¼	4	9	13 5/14	7⅔	2300	10
Saker ordinary	3¾	3½	6	11 11/14	5	1900	9½
Sakeret or Minion ..	3¼	3	4¾	10 3/14	3½	1100	8
Falcon	2¾	2½	2⅓	8 9/14	2¼	750	7
Falconet	2¼	2	1⅛	7 1/14	1½	400	6

Notwithstanding, the science of the theory of gunnery regarding the flight of projectiles through the air were not thought unworthy the careful notice of such illustrious philosophers as Leonardo da Vinci in 1452, followed by Tartaglia (time of Henry VIII.), and Galileo, in his dialogues on motion, published 1646. Later, the names Sir Isaac Newton, Robins, 1742, Hutton, and Sir J. Herschel, bring us down to our own times. But although modifications had been occasionally made in the manufacture of ordnance, the general principles of construction remained unaltered. Captain Stoney tells us, that "Anyone who examines the old guns in the Tower of London, or in the Museum of Artillery, at Woolwich, may see that they are of the same genus as modern smooth-bores, and even notice some specimens quite as soundly and artistically cast as any of those of the present century; nay more, he may infer that our modern cast guns can scarcely be superior to their prototypes in range, power, or susceptibility to rifling.* Captain Stoney attributes this stagnation in the construction of rifled ordnance to the backward state of metallurgical science and mechanism, and not to the ignorance of theory. Thus the manufacture of cast-steel in large masses has only recently been accomplished, whilst rifling machines now work accurately and true to within $\frac{1}{1000}$ of an inch.

But, after all, it is not with rifling that we have to do in this paper, which is intended more to compare the size and weight of the pieces of ordnance ancient with modern, and to let alone all questions of their comparative energy, velocity, and penetrative power. Having premised this, we now proceed to consider our modern monster ordnance. As first examples, although not illustrated, should be quoted the French mortars, with shells of 13-inch diameter, which they threw into Cadiz from a long range at its siege in 1810. These notable pieces of ordnance (their weight is not given, but one of them may still be seen raised as a trophy in St. James's Park, London), were invented by Colonel Villantroys, and called cannon-mortars; they were cast at Seville, and being placed in slings, threw projectiles over Cadiz, a distance of more than 5000 yards.† To obtain this flight the shells were partly filled with lead, and the reduced bursting charge was too small for an effective explosion. Towards the latter end of the siege of Antwerp, in 1832, a mortar cast at Liège was placed in position against the citadel. It weighed 7 tons, and threw shells of 23·6226 inches diameter, which did but little actual execution, but produced a great moral (or rather demoralising) effect. This mortar was afterwards burst at practice with a charge of 9 kilos. (about 20 lbs.). Although the French adopted the Paixhan shell-guns as early as 1822, and General Millar introduced 10-inch and 8-inch shell-guns in 1833, the effect of horizontal shell fire from guns of *very large bore* was only fully appreciated by the British authorities in 1855, in the early part of which year two experimental malleable-iron guns of 13-inch bore were ordered of Mr. Nasmyth, but the idea was given up and the guns counter-ordered. In the following year Messrs. Horsfall, of the Mersey Ironworks, Liverpool, completed the first wrought-iron 13-inch gun of 22 tons weight, length 15 feet 10 inches, which projected with great success solid shot each weighing 280 lbs. to a range of 6000 yards, with a charge of 50 lbs. of powder at a point-blank elevation. This famous piece, the first of its kind, was presented to the nation, and is now mounted at Tilbury Fort. But slightly subsequent in date to the last-mentioned piece, come Mr. Mallet's monster 36-inch mortar, which if not the heaviest pieces of ordnance ever built, may certainly claim a pre-eminent position among all pieces either ancient or modern (the great gun of Moscow not excepted) as regards the weight of their projectiles, which when filled weigh nearly 3000 lbs. a-piece. These mortars, only two of which were forged and built together, owe their origin to the energy developed by Great Britain during the Crimean War. Mr. Mallet's original design was completed prior to October, 1854, and the manufacture, due solely to the personal responsibility of Lord Palmerston, commenced in 1855 by Messrs. Mare and Co., of the Thames Ironworks, Blackwall, who contracted to supply them at the rate of £140 per ton within ten weeks; they each weighed about 40 tons, and consequently cost £5600 a-piece. Mr. Mallet thus revived the old principle of constructing built-up guns, and next to Professor Treadwell, who first demonstrated the superiority of coiled wrought-iron over steel barrels in 1842, may be looked upon as the modern inventor of the "*ringed structure*" in guns. The fact that an enormous accession of strength could be attained by external rings with initial tension being suggested to him by Mr. Clarke's work on the Britannia Bridge in 1850.

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* "Text-Book of the Construction and Manufacture of Rifled Ordnance in the British Service." By Capt. F. S. STONEY, R.A., and Lieut. CHARLES JONES, R.A. Royal Gun Factories, 1872.

† At the siege of Cadiz cast-iron shells filled with lead, forming projectiles of great strength and density, were thrown from mortars to a distance of 3¾ miles. *Vide* "American Artillery Course," p. 69.

The mortar may be shortly described as composed of a massive cast-iron base about 7½ tons, in which is fitted a wrought-iron breech piece in which is bored the chamber proper, strengthened externally by two layers of wrought-iron hoops and one heavy ring. On this rests the chase in three lengths, each of two thicknesses, tied down to the base with longitudinal bars or ties connecting the breech and muzzle rings. In consequence of the failure of the contractors the mortars were not actually finished until a year and ten months after the order, long after the termination of the war, being finished by Messrs. Fawcett, Preston, and Co., from forgings supplied by Horsfall and Co. The author had the pleasure of being present when some of the experiments were made with the first of these mortars, one of which was mounted for this purpose in the Woolwich Marshes. The shells of nearly 3000 lbs. weight had a capacity for nearly 500 lbs. of powder, and were thrown to the maximum observed range of 2759 yards with a charge of 80 lbs. of powder, the charge being arranged in bags by a gunner standing in the bore of the mortar.

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* The Story of the Thirty-Six Inch Mortars of 1855 to 1858. By Major-General Lefroy, C.B., F.R.S., R.A. "Proceedings of Royal Artillery Institution, Woolwich," vol. vii., No. 4, 1871.

The shells, which cost by contract about £16 a-piece, after describing their trajectories through the air with a slow and noble motion,* penetrated into the moist soil to a depth varying from 20 to 30 feet. It is to be regretted that only nineteen rounds in all were fired, the great expenses incident on the repairs of defective rings, wedges, &c., led to the then Secretary of State for War, General Peel, putting an end to further experiments. Mr. Robert Mallet attributes the comparative failure of his mortars to the rapid combustion and *brisante* quality of the brutal large-grain cannon-powder employed; and, doubtless, had pebble- or prismatic-powder been then invented and employed, the results might have been far more satisfactory. It is not too late to repeat these experiments yet, and the realisation of Mr. Mallet's cherished plans may not be beyond the bounds of possibility. The second of the two mortars, which has never been fired, is mounted in the Arsenal at Woolwich, where it forms a conspicuous object; whilst the first, having been dismounted from its crumbling bed by the agency of gun-cotton, still lies, perhaps not uninjured, in the Woolwich Marshes.

Superior in weight to the Mallet mortar, the American Rodman guns do not throw such heavy projectiles; but still as smooth bores, the 20-inch guns, "*Beelzebub*" and "*Puritan*," the 1100-pounders, are formidable weapons of over 50 tons weight. Unfortunately a diagram with detailed measurements of these guns could not be obtained in time to be inserted in the accompanying illustration; but their projectiles are shown for the sake of comparison. These cannon, shaped somewhat like a huge soda-water bottle, are cast-iron shell guns, cooled from the interior; at present, however, they may be looked upon as merely experimental pieces, and they would give no signs of injury before bursting. Lieut.-Colonel Owen rightly points out that the bursting of one of these guns would probably completely paralyse a ship's crew and destroy all confidence in them. Our wrought-iron gun, on the other hand, always gives timely notice by the tell-tale gas-escape channel if any injury happens to the interior steel tube, and an explosive burst is all but impossible with proper powder if not with other explosives. The great 1000-pounder of 50 tons, which was exhibited at the Paris Exhibition by Herr Krupp, of Essen, in 1867, must be remembered by all who saw it on that occasion. The manufacture of this steel gun continued during night and day for sixteen months at a cost of £15,750, and resulted in this unique specimen. It has a forged inner tube strengthened with three layers of rings over the powder-chamber and two layers over the muzzle portion; the rings having been forged from ingots without welding. All these last-named pieces of large ordnance may be looked upon as experimental weapons, and therefore hardly come within the scope of comparison with the mediæval ordnance which were in actual use, and served in action, sieges, &c.; and therefore the first service gun which we have to compare in weight and size of piece, bore, and projectile, is the lately adopted English 35-ton gun. This has been so lately described in the "Quarterly Journal of Science" as to need no further detailed description, which is familiarly known to all interested in heavy artillery. The first of these which was built, "The Woolwich Infant," notwithstanding the injuries it sustained during the crucial tests to which it was subjected at proof, promises well for the future;[*] and others have been and are being manufactured. Already nine others have passed the proof, and four more are all but ready for the proof-butts. But however suitable for naval purposes (for instance, the four guns of the *Devastation's* turrets will be able to hurl simultaneously a concentrated broadside of 1½ tons weight of iron projectiles on any given object), every artillerist agrees that they are not long enough for our sea defences on land. As it is, we have found to our cost that the muzzles of our 9-inch and 10-inch guns do not project far enough beyond Colonel Inglis's iron shields in the embrasures of our lately constructed forts at Portsmouth and Plymouth; and from late experiments it has been found that when the guns in these new-fangled embrasures are traversed extreme right or left with extreme elevation (about 11°), the blast of the explosion at the muzzle is felt with such violence within the casemate that it would be impossible (in spite of the massive cable mantlets erected inside to avert its effect) for a gun detachment to fight the gun, whilst the shields themselves after many rounds would be severely racked: the projectile when it leaves the muzzle passing within an inch (if not less) of the outer edge of the shield-plates.

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* The hemispheres of these fine shell being painted black and white, the gyrations were distinctly visible to the naked eye. Attempts were made without success to trace the trajectory of these great globes by means of photography, also by following with the point of a fine pencil the apparent foreshortened path of the shell on the ground-glass plate of the camera previously divided into squares.

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[*] The defective inner steel tube of the "Woolwich Infant" is to be replaced by a new one, when it will be as good as ever it was.

In addition, a considerable portion of energy is lost in so short a gun, for when large charges are fired a certain amount of the pebble-powder is thrown out of the muzzle unconsumed, and there is no doubt that a greater velocity and penetrative force will be given to the projectile by lengthening the gun. Consequently a new gun is to supersede the S.S. 35-ton gun, and we may hope shortly to see a L.S. 36-ton "Infant" at least 3 feet longer than its elder brother, and its performances at Shoeburyness will be well worth looking forward to with interest. Preparations have already been commenced at Woolwich for the manufacture of the huge forgings which will be required, such as a stupendous new steam-hammer of 30 tons, capable of striking a blow of many hundreds of tons, and other appliances. Taking the 35-ton 12-inch gun as the type, we need do no more than allude to the 12-inch of 25 tons, the 11-inch of the same weight, and the 10-inch of 18 tons. Another 18-ton gun of the *Hercules* it appears has lately (30th May) been permanently disabled when at target-practice off Portland by the premature bursting of a shell in the bore near the muzzle of the piece. As usual, it would seem that the shell broke through its stud-holes where the rifling offers the maximum resistance to their escape, both the steel lining and outer chase coil being split. This is the third gun of its kind which has been thus injured on board the same ship during the past three years. The 12, 9, 7, and 6½-ton guns, together with the 64-pounder, finish the tale of our present wrought-iron guns, whose projectiles are shown on the plate. And now for our cast-iron and bronze pieces, which are not yet obsolete, for although rifled guns have come into fashion, smooth-bore must constitute for some time, if not always, a considerable portion of our armaments. The Woolwich gun-foundry, established 1717, was virtually superseded by the forge in 1859,* the date of the last bronze gun being cast there. The few cast-iron guns which are occasionally required to keep the stock in store up to the specified number are obtained by contract.

The two heaviest pieces are the well-known Dundas 68-pounder of 112 cwts., 1841, and the new pattern 13-inch sea-service mortar of 5 tons, 1857. These are shown for the sake of comparison as illustrating our heaviest pieces during the first half of the nineteenth century, since the end of which such tremendous strides in the art of gunnery have been made. The old 110-pounder or 7-inch Armstrong breech-loader is also given, and illustrates the transitional epoch from the heavy smooth-bores to the heavier rifled pieces with elongated projectiles. General Lefroy, in illustrations of the guns left at Mont St. Michel, contrasts the 68-pounder and the 110-pounder Armstrong with Michelette and Mons Meg, which suggested the present paper. Dr. Déthier also draws a comparison between the American 20-inch Rodman and the cannons of Muhammad II.

It should be remarked that there are still in our own service pieces of ordnance, not yet obsolete, in whose construction can be easily traced the ancient traditional proportions descended from the earliest cannon, the "*bombards*" and "*crakys*" of war in olden days; these will readily be detected by anyone narrowly observing their sections; and, properly speaking, a diagram showing a section should have appeared in the plate for the sake of comparison. I refer to the brass coehorn howitzers of $4\frac{2}{5}$ inch howitzers cast at Woolwich in 1738, and still retained in the service, together with the royal and coehorn mortars of about the same date. These apparently insignificant pieces, although small, are very useful for colonial and mountain service or in the advanced trenches of a siege attack, whilst the royal mortar is fitted for firing Manby's life-saving apparatus.

Whilst comparing the size of the guns and projectiles of modern days with those of the middle ages, it cannot have failed to strike the observant reader that there is much in common with both; but beyond this all comparison ceases; for instance, it would be absurd to compare the rough hollowed elm block in which the gun from the *Mary Rose* man-of-war is mounted with either Scott's naval gun-carriage and slide or Moncrieff's elaborate elevating gear. In fact, we have only to look at the numerous crafty mechanical details involved in a simple double-plate wrought-iron carriage and platform with their fittings, whether American, Elswick connected screw-shaft, or hydraulic or other compressors, not to see that it is more in the delicate appliances, such as fuses, and minutiæ of adjustments, such as sighting, &c., that our real superiority obtains over the noble and massive, yet rugged ordnance, of our ancestors.

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* Notes on Cast-Iron and Bronze Ordnance. By Captain F. S. STONEY, R.A., Royal Gun Factories, Woolwich. 1867.

NOTICES OF BOOKS.

Remarks on Recent Oceanic Explorations by the British Government, and the Supposed Discovery of the Law of Oceanic Circulation, by Dr. W. B. Carpenter, F.R.S. By WILLIAM LEIGHTON JORDAN. Buenos Ayres: Imprenta Inglesa, 55, Calle de Cuyo. 1871. 56 pp.

THERE have been promulgated several theories attempting to explain the phenomena of oceanic circulation; and among these that best known to the scientific public, because most sedulously advanced, originates with Dr. Carpenter. This author seems to possess a peculiar and often very convenient disregard for the objections of his *confreres* in science, more especially when these objections are unanswerable, finding his reward in the applause of a too credulous public. Despite the publicity given to the facts advanced by Mr. Jordan in 1868, Dr. Carpenter, we believe, still continues to ignore them. An adage says, "Facts are stubborn things," consequently there cannot be much surprise that they should again occur to Dr. Carpenter's notice. Yet it seems strange that in such a tangible science as geography these facts should not have arisen dominant once and for all. To this there appears to be only one answer, namely, that geography is taught ordinarily in generalities; the exceptions or anomalies to these generalities being omitted by or unknown to the authors of our books of reference. In dealing with the facts brought forward by Mr. Jordan as opposed to Dr. Carpenter's theory, we shall quote extensively from the pamphlet sent us to review.

In the first place Mr. Jordan says, speaking of the explorations, "My object is not to descant on the unquestionable merits of these researches as regards the discovery of facts, but to deal with deductions made by Dr. Carpenter from them, which I consider erroneous." He then proceeds to the consideration of Dr. Carpenter's arguments regarding the Mediterranean and Baltic, and assuming them to be irrefutable, passes to the unsound assertion that "a vertical circulation must, on the same principle, be maintained between polar and equatorial waters by the difference of their temperatures.

"As regards this temperature theory," continues Mr. Jordan, "two incontrovertible facts exist, which combined are sufficient to annihilate it. The one, the fact that both in the Atlantic and Pacific Oceans the cold under-currents flowing towards the equatorial regions tend to the eastern parts of those regions, where they rise to the surface to flow westwards, becoming gradually heated in their course until, on the west of each ocean, they branch off northwards and southwards as warm currents. The other fact is, that if water were set in motion between the Equator and the Poles by differences of temperature, the rotation of the earth would immediately act upon it, tending to carry that moving towards the Equator westwards, and that moving towards the Poles eastwards; so that one of the most striking features of the circulation would be the tendency of the cold water to flow towards the Equator on the west of the ocean, eastwards through the equatorial regions, and to branch off northwards and southwards as warm currents, on the east of the ocean. These general features are exactly the reverse of the general features of the circulation which actually exists; and therefore nothing more is requisite to explode the theory; for what *must* be the result when fact and theory clash like this?

"Besides this broad discordance with actual facts, the details of Dr. Carpenter's theory are open to criticism. Is not the assertion, that a difference of level in the ocean will cause a surface current, rather reckless? Has it been certified by experience? or can any recorded phenomena be adduced in support of it?"

The system of upper and under currents through the Strait of Gibraltar and the Sound, Mr. Jordan goes on to show to be the "result of differences in specific gravity, as explained by Captain Maury's theory, which had better be left in its original simplicity, for this modification, with which Dr. Carpenter has attempted to encumber it, is not an improvement, but an erroneous complication."

"Captain Maury says wherever there is a 'difference of specific gravity between sea-water at one place and sea-water at another,' 'whether it be owing to difference of temperature or to difference of saltness, &c., it is a difference that disturbs equilibrium, and currents are the consequence. The heavier water goes towards the lighter, and the lighter whence the heavier comes; for two fluids differing in specific gravity, and standing at the same level, can no more balance each other than unequal weights in opposite scales of a true balance. It is immaterial whether this difference of specific gravity be caused by temperature, by the matter held in solution, or by any other thing; the effect is the same, namely, a current.'* This is sufficient to account for the Gibraltar current without the necessity of a surface current caused by difference of level, to set the circulation in motion. The Atlantic water which supplies the waste caused by evaporation in the Mediterranean flows in as a surface current because it is lighter than that of the latter sea, which the action of specific gravity consequently carries out below it.

"The currents in the Experimental Illustration of the General Oceanic Circulation in which water in a long narrow trough, as exhibited before the Royal Geographical Society, is heated at the surface of one end by a lamp and chilled at the other by ice, can be explained by the action of difference in specific gravity alone; the difference in temperature causes a difference in specific gravity, and for the restoration of the equilibrium a surface current of the lighter flows towards the denser water, whilst at the same time an under-current of the latter flows towards the former. The expansion caused by heat tends to raise the level at one end, and the contraction caused by cold tends to depress it at the other end; but if this difference of level were produced without any difference in the specific gravity, it would, in an open ocean, as already shown, be restored not by currents, but by a tidal movement of the ocean, the higher level sinking and the lower rising simultaneously.

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* Physical Geography of the Sea, par. 406.

"It appears that in the Mediterranean the surface heat, resulting from the action of the sun's rays, causes evaporation, which *lowers* the level and *increases* the density of water; and therefore when, in treating of the general oceanic circulation, Dr. Carpenter says that the level of Polar water is reduced and its density increased by surface cold, it might be expected that he would admit that the same effects are caused in the Equatorial regions by surface heat, or at least give some explanation as to why it should be otherwise. But instead of this Dr. Carpenter, without explanation, deliberately asserts that in the Equatorial regions the level of the water is *raised*, and its density *diminished* by the surface heat to which it is exposed: that is to say, that surface heat in the Equatorial regions causes exactly the opposite effects to those which it causes in the Mediterranean. If the observed effects in these two regions are really so diametrically opposite, can they be the result of the same cause? or may not the difference in the effects rather be the result of a difference in the ratio which the evaporating action of the sun's rays in the two places bears to the respective amounts of fresh water supplied by rivers and rain? But has it ever been shown that, whatever be the cause, there actually are such different effects in the two regions, or is this another reckless assumption to suit the exigencies of a preconceived theory?"

But by no means do Dr. Carpenter's anomalous deductions end here. Besides the vertical circulation resulting from differences in temperature, Dr. Carpenter says that "the Gulf Stream forms part of a *horizontal* or *superficial* circulation in the North Atlantic, of which the Trade Wind constitutes the *primum mobile*." Thus the general features of the theory seem to be that the difference of temperature in Polar and Equatorial regions causes a vertical, and the Trade Winds a horizontal circulation throughout the ocean. This is brought forward not merely as a theory by which a system of circulation might be caused, but as an efficient cause of the circulation which actually exists in the ocean.

Three years ago Mr. Jordan, making use of his own and Captain Maury's arguments, endeavoured to show the inefficiency of the winds as a cause for the existing currents of the ocean. He said, "'Theoretically considered, it appears plausible enough to assume that the winds must tend, to some extent, to cause a system of currents, by driving the surface water before them; which, wherever it accumulates against obstructions, must tend to run off in streams. But, practically considered—that is to say, considering what are the actual winds which blow, and what the actual currents of the ocean—it appears to us incomprehensible how any one who studies these systems of aërial and oceanic circulation can reconcile them as cause and effect. It appears to us surprising how, considering the enormous volume and weight of water borne along in the oceanic currents, any one can help doubting the power of the comparatively light atmosphere to keep such a mass in motion, even if it were shown that the *course* of the oceanic currents corresponded with that which would naturally result from the action of the winds which exist. But when it is found that the winds tend to a great extent to neutralise each other, and that, even in the region of the Trade Winds, where the power of the winds is greatest, ocean currents, even on the surface of the ocean, run across and against those winds, whilst in the lower strata immense under-currents run their course regardless of the winds which blow above; it then seems surprising how any one can consider that the position and direction of the ocean currents which exist are in accordance with the current-creating action of the winds, even if it be assumed that the latter are sufficiently powerful to control the enormous volume of water which is carried along in those currents.'"*

He also endeavoured to show the inefficiency of the Temperature theory. And after making use of Sir John Herschel's arguments, said: "'Besides the objections urged by Sir John Herschel against the theory which makes differences in specific gravity the prime cause of the currents of the ocean, we may here observe that, if differences in specific gravity, resulting from the difference of temperature and other conditions in Polar and Equatorial regions, were the principal cause of ocean currents—in consequence of the tendency of the heated and cold water to exchange positions in order to re-establish their equilibrium in specific gravity—then the heated water flowing from the Equator would be under that influence of change of latitude which tends to carry it eastwards, and the cold water from the Polar regions would be under that influence of change of latitude which tends to carry it westwards; so that, therefore, the warm water would naturally flow from the Equator on the east side of the ocean, and the cold water as naturally flow towards the Equator on the west side of the ocean; whereas, in fact, with the actually existing currents of the ocean, the very reverse is the case: the cold water is brought to the Equator partly by currents running towards the Equator on the eastern side of each ocean, and partly by under-currents rising to the surface chiefly in the eastern parts of the ocean; then it flows westwards through the Equatorial regions, and flows from the Equator on the west of the ocean as warm currents, having been heated during its course through the Equatorial regions.'"*

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* Vis-Inertiæ, p. 62. London: Longmans, 1868.

Afterwards alluding to this in connection with the winds he remarks that: "'The idea of the Trade Winds being considered a sufficient cause to account for this complete reversal of the course which the currents would naturally take under that influence of the axial rotation of the earth is one which I do not suppose any one will seriously maintain.'†

"I suggested the action of the winds and specific gravity as a means by which a system of oceanic circulation might be caused, but at the same time rejected it as too preposterously at variance with the actually existing circulation to be entertained by any one conversant with the subject. In this I was mistaken; for Dr. Carpenter now brings it forward in an elaborate article as the true theory of the existing oceanic circulation.

"But how has Dr. Carpenter succeeded in making this theory appear to explain the existing currents of the ocean?

"First: by utterly ignoring that influence of the earth's rotation to which I have alluded. This is the force which, according to Halley's theory of the Trade Winds, gives those winds an easterly direction, making them N.E. and S.E. winds, instead of N. and S. It is the force indicated by Captain Maury as the cause of the Gulf Stream tending eastwards after it leaves the Gulf of Mexico. It tends to carry the Gulf Stream eastwards, because that current is running from the Equator, and at the same time it tends to carry the cold Labrador current westwards, because the latter is running towards the Equator. Thus, by its action, those currents running in opposite directions are made to flow side by side without intermixing.

"If warm water at the Equator and cold water at the Poles rush towards each other to re-establish their equilibrium, why do not the warm waters of the Gulf Stream and the cold waters of the Labrador current, when brought into juxtaposition, intermingle and at once restore their equilibrium? It is simply because they are held in the grasp of the gigantic power created by the earth's rotation, and the puny powers created by differences of temperature or specific gravity are impotent in its presence. These latter appear in Dr. Carpenter's theory to be the paramount forces, to which the Winds are secondary. If, then, the force of the above action of the earth's rotation mocks the forces created by differences of temperature where the latter do not act in concert with it, how can the lesser force of the winds be supposed to control it?

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* Vis-Inertiæ, p. 59. London: Longmans, 1868.
† *Ibid.*, p. 66.

"Secondly: without a word of argument, or a shadow of proof, Dr. Carpenter assumes that differences of level in the ocean must cause surface currents from the higher to the lower levels; and such currents, flowing into the Polar regions, he makes the first impetus of the circulation; so that the fact that differences of level in the open ocean are naturally restored by tidal movements, and not by currents of any sort, cuts away the tap-root of his theory.

"And thirdly: without any explanation, Dr. Carpenter treats the action of surface heat as causing exactly the opposite effects in the Equatorial regions to those which it causes in the Mediterranean. With most astounding and glaring inconsistency he makes (not by argument, but by mere assertion) the same cause produce different effects, just as the exigencies of his theory in different parts of the ocean require. Besides these things, considering also minor details to which I have not alluded, I could scarcely have believed it possible that such loose and reckless theorising could have been perpetrated by a Fellow of the Royal Society, and still less by a man selected by the British Admiralty as their scientific represéntive, and this too in treating of a subject with which the acceptance of the latter post makes it his special duty to be well acquainted."

Considering that, according to Dr. Carpenter's theory, the great predominant current-creating force is in the Polar regions, it might be expected that some facts would be brought forward in its support; but to this Dr. Carpenter does not condescend; for after the assertion that "the surface flow of Equatorial water towards the North Polar area is a fact universally admitted," and an argument regarding the course from the Equatorial regions of the water which "passes north and north-east between Iceland and Norway towards Spitzbergen," he branches off to draw distinctions between "the *mere* Physical Geographer" and "one who takes a *scientific* view of the matter"—rather an unhappy distinction for the author himself it would appear. Certainly the fact referred to is admitted; but will Dr. Carpenter contend that in the latitude of the north of Norway the volume of the surface-flow of warm water northwards on the east of the ocean is anything like equivalent to that of the surface flow of cold water southwards on the west of the ocean? And it should also be observed that in those high latitudes, according to the theory of the current-creating action of the earth's rotation, there exists, west of the surface flow of warm water, an under current of the same flowing northwards with a surface current of cold water immediately above it flowing southwards. A part only of the warm current is tilted up to the surface on the east of the ocean, whilst the remainder under-runs the cold current flowing in the opposite direction. "Be this, however, as it may," continues Mr. Jordan, "why is it that no more facts from that region, so important to the theory, are brought forward in its support? Is it in consequence of a consciousness that nearly all genuine facts from thence would be death blows to the theory? It seems to me that it would be scarcely possible to invent any theory by which, in the absence of other causes, a system of oceanic circulation might be caused that could, in those regions, be more completely at variance with the results of actual researches than this temperature theory of Dr. Carpenter's."

Much as we should like to introduce an account of the arguments diffidently advanced by Mr. Jordan, their length precludes such a course in a notice of his pamphlet. But his views may be thus recapitulated:—

"First: the very basis of Dr. Carpenter's theory requires that the force of gravitation should re-adjust the level of the ocean, by bringing down the level in the Equatorial regions and raising it in the Polar regions, in consequence of the existence of the reverse effects resulting from differences of temperature. In reply to this, practical researches tend to show that the action of differences of temperature and other conditions between Equatorial and Polar regions has the reverse effect from that which Dr. Carpenter assumes them to have—that they tend to lower the level in the Equatorial and raise it in the Polar regions; so that the re-adjustment to be made by the force of gravitation is in the opposite direction to that required by Dr. Carpenter's theory.

"Secondly: Dr. Carpenter assumes that the action of gravitation would cause a surface current through the ocean from the higher to the lower level: and to such currents flowing into the Polar regions he attributes the first impetus which sets the circulation in motion. In reply to this it has been pointed out that the action of gravitation would, in the open ocean, tend to re-adjust such differences of level by tidal movements, the higher levels falling and the lower rising simultaneously without causing any current. So that therefore, even if Dr. Carpenter were right in assuming the level of the Polar to be lower than that of the Equatorial regions, no such surface currents would be created by that difference of level as those to which he attributes the first impetus which sets the circulation in motion.

"Thirdly: according to Dr. Carpenter's theory, in the Polar regions the surface currents flow towards and the under currents from the Poles. In reply to this, practical researches tend to show that the very reverse is the case:—that the cold waters pour away from the Poles chiefly in the upper strata, whilst warm currents flow beneath them towards the Poles. So that the vertical circulation in the Polar regions—the great paramount force-creating region, according to Dr. Carpenter—appears to be the reverse of that necessitated by his theory.

"Fourthly: if a circulation were caused by differences of specific gravity, or any other effects resulting from differences of temperature between the Equatorial and Polar regions, it has been shown that the currents would flow towards the Equator on the west of the ocean, eastwards through the Equatorial regions, and from the Equator on the east of the ocean, and this course, which would certainly result from Dr. Carpenter's theory, is exactly the reverse of that of the currents which form the horizontal circulation in the Equatorial regions.

"Fifthly: Dr. Carpenter adapts the Mediterranean theory to what is known of the vertical circulation of the temperate and equatorial regions by reversing the action of surface-heat from that admitted in the former regions; this strategic movement, however, seems to be a descent from bad to worse, for by it the theory appears to be placed in direct antagonism with the source of its own creation; namely, the vertical circulation in the Polar regions. And—to follow the parallel suggested in Sir Roderick Murchison's contingent eulogy—this gross deviation from consistency has led Dr. Carpenter into such confusion that where veins and arteries interlace he has taken up veins for arteries and treated arteries for veins, even supposing his location of the heart to be exact; but in this he has made a still more grievous mistake in imagining that source of circulation to lie divided in the cold extremities of the earth instead of in the vast expanse of the Equatorial regions.

"Dr. Carpenter's theory of the action of surface-cold may prove most valuable in the consideration of minor details of oceanic circulation. But as a cause of the main features of the existing circulation it is so absurdly incongruous and inadequate that in this Essay Dr. Carpenter must be said to have lowered himself to the level of a '*mere*' theorist. The negative reply to the question whether the '*so-called*' explanation of oceanic circulation is or is not the '*real*' explanation, is so glaringly obvious that it is surprising how any one acquainted with the subject could be so infatuated as to take the false course in which Dr. Carpenter has involved himself. It is a degradation of the term '*scientific*' to apply it to such theorising. How much more really scientific—how much nobler is the spirit of the true 'Physical Geographer' who completely subordinates theory to fact. This is the spirit which breathes through Maury's writings, and enables the reader to turn over the pages with a refreshing confidence that he need fear no delusion. A recently increasing departure from it in too many English scientific writers has culminated in this audacious effusion of Dr. Carpenter's. If such essays are to be brought forward by leaders of English science, history will record a degradation of English intellect in the present generation; and the laurel which the civilised world by acclamation placed on England's brow, in honour of Newton's discoveries, will soon be torn away to be worn elsewhere."

Apart from the valuable theory which Mr. Jordan has advanced in his work, we think he has performed a duty in thus clearly proving the errors of a theory too assiduously expounded. But it must be said that we lay down Mr. Jordan's pamphlet with feelings of the most intense surprise—surprise that such a theory should meet with the slightest favour, and that Dr. Carpenter should have evolved it in any moment but those of "unconscious cerebration."

Coal Economy. By FRED. CHAS. DANVERS, Assoc. Inst. C.E., of the Public Works Department, India Office, &c. London: W. H. Allen and Co. 1872.

WHILE public attention has of late years been directed again and again to the serious waste of coal consequent upon our present systems of coal mining, and to the recklessness with which the fuel is too often consumed, it is curious that little or nothing has been written on the injury and waste which the coal suffers after it emerges from the pit's mouth, and during the successive stages through which it passes before reaching its final destination.

Yet this loss is by no means insignificant; for it is obvious that the coal in the course of being screened, and during its transport, whether by land or water, must be continually subjected to movements which tend to cause disintegration, and inevitably result in the formation of more or less small and comparatively useless coal. It is pleasing to find that this neglected phase of coal economy has received the careful attention of Mr. F. C. Danvers, who in the work before us discusses the several sources of waste, and points out the best means of utilising the small coal, whilst incidentally he offers much useful information on the machinery employed in connection with the mineral traffic.

It is not with the waste in underground working that our author has to deal. That question was fully examined by the Coal Commission, and Mr. Danvers's work begins exactly where that of the Commissioners ended. Suffice it, then, to say that in the steam collieries at least 40 per cent is usually lost in working by the "pillar and stall" system, and about 15 per cent by the "long wall" system. If the small coal be raised to the surface with the large coal, the pit is said to be worked on the "altogether" principle; if the small coal is left underground it is worked on the "separation" principle. In the former case as much as one-half of the output may consist of "small," whilst in the latter case only from 5 to 10 per cent passes through the screens. The author describes the construction of several forms of screen used in the South Wales coal-field, and in the neighbourhood of Newcastle—the two localities selected as offering the best examples of modern colliery appliances.

After leaving the screens at the pit's mouth, the coal suffers more or less breakage during railway transit. Mr. Danvers does not, however, think that the amount of disintegration in a waggon increases in proportion to the length of the journey; for after the first few miles the large lumps get firmly seated on a bed of small coal formed by the mutual abrasion of sharp corners. Admitting this, one may question the propriety of screening at the pit, since the small coal thus removed would evidently be useful in filling up spaces between the larger blocks.

It must not be supposed that the injury which coal suffers stops at the end of its journey. If the fuel be stored in open air it gradually disintegrates, and at the same time loses much of its heating power: indeed, the value of steam coal may actually be reduced one-half by exposure to the air for six months. It is consequently important that coal should be protected in the depôts in which it is stored; and of late years much attention has been paid to the construction of such buildings.

After the employment of even the most approved machinery in connection with coal traffic, there must needs be a considerable amount of almost valueless small coal—*duff*, *slack*, or *waste*, as it is usually called—and it remains to see how this can be profitably utilised. Without following the author into his long discussion of the principles of combustion and the economic use of fuel, we may cite his opinion that the method at present most convenient and most generally applicable for utilising small coal is that of manufacturing it into artificial or patent fuel. Several methods devised for this purpose are here described: different patentees have suggested the use of pitch, tar, starch, and alkaline silicates as the cementing material by which the slack is formed into blocks. The author recommends that the coal be washed to remove as far as possible the shale and other associated impurities, and then be moulded into blocks by means of a mixture of starch and bituminous matter.

Before closing the present work it is right to state that the information which it contains was originally collected by Mr. Danvers with the view of forming a Report for presentation to the Indian Government.

Coal mining is at present in its infancy in India; but the rapid extension of the railway system—not to speak of other sources of demand—creates a growing increase in the want of fuel—a want which the forests, in spite of all conservancy, cannot continue to supply, and which must ultimately necessitate the development of the coal-fields of India. But in a country where the coal resources are but limited, and where the coal is for the most part extremely tender and liable to suffer spontaneous disintegration from the large proportion of associated iron pyrites, it is evident that the greatest care and economy should be exercised in the transport of the fuel. Hence Mr. Danvers's subject is invested with peculiar interest in our Indian possessions. Nevertheless his book contains so much that is valuable, that it may be studied with almost equal profit at home by all who are practically interested in the welfare of the British coal trade.

A Text-Book of the Construction and Manufacture of the Rifled Ordnance in the British Service. By Captain F. S. STONEY, R.A., Assistant Superintendent Royal Gun Factories; and Lieutenant C. JONES, R.A., Instructor Royal Gun Factories. Corrected up to January, 16th, 1872. Printed under the Superintendence of Her Majesty's Stationery Office.

CAPTAIN STONEY and Mr. Jones, in their carefully compiled Text-Book, supply a want which has long been felt by students in the Royal Gun Factories at Woolwich Arsenal. Both Naval and Military as well as civilian Artillerists have all experienced the great difficulty of keeping pace with the constant and rapid change both in modern ordnance and its *matériel*, more especially since the introduction within the last ten or twelve years of various systems of rifling, followed by their inevitable train of new inventions, in the shape of fuzes, explosives, &c.

This difficulty has hitherto been enhanced from the fact of there having been no authorised text-book to start from as a recognised stand-point of departure.

It is with great satisfaction, then, that we hail the publication of a work compiled by two such competent authorities as the late Assistant-Superintendent and the present Instructor at the Woolwich Gun Factories, to which department of the Arsenal the volume is creditable.

In a technical work of this description there is naturally no room for originality, but a practical gunner can alone fully appreciate the vast amount of nice research required, and the laborious care necessary to collect and arrange the formidable array of minute details which, however apparently trivial in themselves, are in reality of the most practical importance as a whole when brought together within manageable compass.

Such condensation can only result from sound knowledge of the subject and ability on the part of the compilers; and, judging from the result, the authors of the present volume under notice appear to possess both.

The text is well illustrated with eleven lithographed detailed coloured plates, comprising all the wrought-iron muzzle-loading guns, as well as the small steel and bronze Abyssinian and Indian guns, besides numerous woodcuts of details, fittings, &c.

The work commences with a brief historical sketch of our rifled ordnance, from Lancaster's gun in the Crimea, and Colonel de Beaulieu's field pieces at Solferino, down to the present Prussian system of Krainer, and our own Fraser cheap construction Woolwich guns; then follows the consideration of the various rival systems of rifling up to the latest date; and our authors, in conclusion of Chapter I. remark, "that the tests and trials bearing on this question (that of construction), while exemplifying the pains taken to obtain the best war *matériel*, cannot fail to satisfy the most sceptical, that the present construction of our guns is sound and durable, and also that we have made marked progress of late years in heavy ordnance. In Chapter II. we have Hart's, Armstrong's, Whitworth's, Palliser's, Rodman's, and Fraser's systems of construction discussed, and our British ordnance is compared with foreign to the manifest advantage of the former. "For supposing the American cast-iron guns are as durable and as little liable to burst as our sinewy guns of wrought-iron, and that their *apocryphal* charges are actually used, our guns possess the great advantage of being able to *pierce* armour-plates with shot, nay even with *shell*, which the American guns could only crush or '*rack*' with solid shot. Various examples of Prussian guns bursting explosively are also given as a proof that the uncertain character of steel renders it a dangerous material, and that we must not trust it until greater improvements take place in its manufacture. In Chapter III. the materials for ordnance, such as bronze, cast-iron, steel, and wrought-iron are compared, and their physical properties described. Its deficiency in hardness, however tough and tenacious the metal, points out bronze to be unsuitable, except under restricted circumstances, for ordnance. However valuable the hardness of cast-iron, yet its brittleness renders it unsafe, and only useful for converted guns with a wrought-iron lining. The defects of steel, also, may be stated to be brittleness, uncertainty, and deficiency in extensibility, when strained beyond its elastic limits, which render it unsuitable for the exterior portions of a gun; at the same time, from its hardness, high tensile strength, and freedom from flaws and defects, it is well suited for the inner barrel. Lastly, wrought-iron is valuable as a gun material, on account of its comparatively high tenacity, combined with its malleability and ductility. The next chapter is taken up with an account of the principal operations in the manufacture of wrought-iron ordnance, the machinery employed, the methods of forging, welding, and coiling on a large scale, the lathes, rifling, and other machines. Further on we have the manufacture of the breech-loading Armstrong guns, of which, although suspended latterly, a knowledge is required by officers who have to deal with this class of guns in the service. We will now proceed to watch the progress of a 7-inch Fraser cheap-construction gun through its rough process of manufacture, many details necessarily being omitted. First, the gun consists of the following parts:—

I. An inner barrel or tube of steel, called *the A tube*.
II. Two single and slightly taper coils united together, called *the B Tube*.
III. A triple coil, a trunnion ring, and a double coil, all welded together, called *the breech-coil or jacket*.
IV. A cascable.

I. The steel for the A tube is received from the contractors in the form of a solid ingot and severely tested. It is next roughly bored and turned and becomes a tube, which is next toughened by being thoroughly heated to a certain temperature, and then plunged in a bath of oil until cool. This process frequently warps the steel tube, and not unfrequently causes the surface to crack; the barrel is therefore slightly turned and bored again to make it straight inside and out, as well as to remove any slight flaws; and for fear some of these flaws should escape notice, the tube is now subjected to the water-test. By certain mechanical contrivances the tube is filled with water, which is subjected to a pressure of 3½ tons per square inch; if no moisture exudes on the exterior of the barrel under this pressure the tube is passed as sound.

II. The B tube is composed of two coils made and welded together in the usual way, and rough- and fine-bored to the degree of smoothness requisite for close contact with the steel A tube on which it is to be shrunk; and here it may be remarked, that it is found easier to turn an inner tube to fit an outer one than *vice versa*.

III. The triple coil is formed by coiling three bars one over the other and welded under a powerful steam-hammer and turned down, being fitted with a shoulder for the reception of the trunnion ring.

The double coil is similarly prepared also to fit the trunnion ring, the trunnion ring being also ready; all three parts are heated to redness, the trunnion ring is dropped upon the shoulder of the triple coil, and the double coil dropped through the upper part of the trunnion ring on the triple coil, and the whole mass placed bodily in a furnace and raised to welding heat; being next placed under the most powerful hammer in the department, six or seven blows suffice to amalgamate the three parts together. The breech coil thus formed is next turned in a very powerful lathe, the trunnion ring slotted smooth in a self-acting vertical machine, and the trunnions themselves turned down to shape in a break lathe. The jacket is next rough- and fine-bored, and its muzzle end recessed on the inside so as to overlap the breech end of the B tube.

IV. The cascable is first forged from the best scrap iron into an oblong block, then turned cylindrical and a bevel thread cut on it; the button is turned on it, and a hole is drilled through one end for the purpose of screwing it into the gun.

All the parts are now ready for building up.

First the B tube is shrunk over the muzzle of the A tube, and the A and B tubes shrunk up are placed together in a lathe, and they are fine-turned to receive the jacket.

The half-formed gun being placed standing on its muzzle in the shrinking pit, the jacket is heated and shrunk on, and allowed to cool naturally, a jet of water playing up the bore to keep the interior cool.

The cascable is next screwed in, an operation which it may be imagined requires great care, for the front of it must bear evenly against the end of the steel barrel. One round of thread is turned off the end of the cascable, so that there may be an annular space there, which in connection with a channel now cut along the cascable and across the thread, will form a gas-escape or tell-tale hole in case the steel barrel should split at the end. Various finishing processes are next proceeded with previous to proof, which we need only enumerate, viz., fine-boring, second rough cutting of chamber, finished boring, broaching of bore and finishing chamber, lapping, rifling, and temporary venting. The manufacture of the higher natures of guns are on the same principle, and the only difference is in having extra coils. All guns are minutely examined before proof, and gutta-percha impressions are taken of the whole length of the bore in four quarters. The bore of all guns of 9-inch calibre and upwards is also accurately gauged every 3 inches. The proof is based on the highest charge which the gun will fire on service, viz., two rounds of 1¼, the highest battering charge and service projectiles; this will not improbably be altered to the highest service charge with heavier projectiles. After proof the guns are again tested by the water being pumped at high pressure into the bore, and gutta-percha impressions again taken and the bores gauged. If there should be any doubt about a slight defect the gun is again subjected to five more rounds, and if after that the defect does not appear to increase the gun is passed.

The last chapter treats of the important duties of examining, testing, and preserving guns, &c., as to their defects and repairs, &c.

Finally, in a valuable Appendix, are given range tables and fuze scales and other useful information.

We can only conclude by remarking that nothing could be more opportune at the present time than the appearance of this compendious and satisfactory text-book.

The Law of the Winds Prevailing in Western Europe. By W. Clement Ley. With Charts, Diagrams, &c. Part I. London: Edward Stanford. 1872.

This work is the first instalment of what promises to be a very useful record of the main lines pursued by storms in their courses about our own islands, and some of the neighbouring countries. Whilst recording with care observations actually made, both of barometric change and of direction of wind, Mr. Ley attempts to classify the results, and we think with great success; still he himself points out that much more observation is requisite, and the combined efforts of many interested observers are required before much accurate scientific knowledge can be said to have been collected. We wish him and his fellow labourers all success, and we are quite sure that the carefully-prepared diagrams and the systematic character of the records in this work will greatly facilitate the labours of future observers. The description of the origin of circular motion in winds is most clear and luminous, and is capable of being understood by a mere child.

Observations of Comets, from B.C. 611 *to* A.D. 1640, *extracted from the Chinese Annals.* Translated with introductory remarks and an Appendix comprising the Tables necessary for reducing Chinese time to Euoropean reckoning; and a Celestial Atlas. By John Williams, F.S.A., Assistant-Secretary of the Royal Astronomical Society, &c., &c. London: printed for the Author. 1871.

Mr. Williams has done useful work which required a rather peculiar combination of acquirements. It is not many persons who unite a competent knowledge of the Chinese language with an acquaintance with the latest discoveries in astronomy. The work before us is the result, however, of such a combination, and we must thank the author for having undertaken a work requiring so much labour, and necessarily leading neither to profit nor renown. To the few persons who will make use of the lists here given, and they will naturally be few, this work is invaluable, and they will no doubt feel doubly grateful and assured of the accuracy of what is thus prepared for them, as the author furnishes them with the means of testing his accuracy and of going over the ground after him. The Chinese mode of reckoning time from the earliest epoch of the present day is described, and the divisions of the heavens among the same people are fully explained. The labour of explaining all this in a manner intelligible to those previously unacquainted with sinology, of copying, translating, and explaining a great quantity of Chinese records, must have been immense, and the reward is that the present work may become a work of reference for those who may be investigating the paths of comets as in future time they may appear to us.

Geology of Oxford and the Valley of the Thames. By JOHN PHILLIPS, M.A., F.R.S., &c. Oxford: Clarendon Press. 1871.

THE work before us, the excellency of which is attested by the name on the title-page, is calculated from its extremely practical nature to do more for the study of geology than any amount of scientific manuals. To a young man whose mind is opening as minds do open when they are first thrown amidst the new intellectual arena to be found in a University town, a book like this may be of inestimable value. We cannot imagine a present more likely to influence for good the future career of a young man for the first time going up to Oxford than one which should give a purpose to his leisure hours, lead him to notice the world around him, and supply a purpose to the time devoted to recreation and to exercise. Such is Professor Phillips's book. From the Malvern and Gloucestershire hills to the Reculver; from gneiss and granite to the alluvium of the Essex marshes; from Cambrian fossils to bronze celts, the river which more than any other contributes to the commercial superiority of England lays open to the willing student pages upon which are written the history of the great world of nature in a style less difficult to master than the involved sentences of Thucydides, and in a continuous history in which there is no fear of finding more of myth than of fact. We shall hope to see the student, who in the morning plods through the difficulties of the Greek historian, the legends of the Latin chronicler, and the arguments of Greek philosophers, obeying the impulses he receives from our English Bacon, going forth to gain air and exercise, not to a mere bodily athleticism, but, under the guidance of another professor, studying the stone quarries of the neighbouring country, watching the flowing of the water, and collecting day by day evidences of the changes in what now is a river-basin, was more than once a mighty estuary, and has even formed the bed of a glacial sea. The work of Professor Phillips is exhaustive. He traces the history of those who have made the valley of the Thames their special study; and when we remember that this begins with Tradescant of the "Physic Garden," and includes Smith and Buckland, we see that this is almost a history of English geologists. The physical geography of the whole valley and its surrounding hills is carefully treated with diagrams of the appearance of the country submerged to various depths. The tributary rivers receive a due share of attention, and are all traced to their source; and then each geological period has a chapter to itself, in which its various strata are described and localised, the fossils it contains catalogued and delineated, and the theories derivable therefrom remarked and discussed. In one chapter the changes of the earth's surface from upward and downward movement, from the wearing away of rivers, and from the deposit of floods, is exemplified from this one typical river-basin. Finally, a single chapter discusses the economical questions of the amount and quality of the supply of coal, iron, brick and pottery earth, ochre, Fuller's earth, glass, sand, and last, not least, water.

In this way does the Oxford Professor both inculcate the theory and show by practice that observation is necessary to the foundation of this science; that geology is a philosophical study branching off into many kindred sciences, and that it has a practical value for chemist, agriculturist, miner, metallurgist, and engineer; and like every other branch of natural science, it leads from phenomena which our senses can observe to discoveries useful to man in every career.

Volcanos, the Character of their Phenomena, their share in the Structure and Composition of the Surface of the Globe, and their Relation to its Internal Forces. With a Descriptive Catalogue of all known Volcanos and Volcanic Formations. By G. POULETT SCROPE, F.R.S., &c. Second Edition, with Prefatory Remarks, and a List of recent Earthquakes and Eruptions, &c. London: Longmans. 1872.

WE notice the second edition of this exhaustive work on Volcanos, both because it is a long time, thirty-seven years, since the first edition was published, and also because some considerable additions have been made in the present issue. The list of recent eruptions extends from 1860 to the end of August, 1871, and includes those disturbances which are not mentioned in the body of the work nor in the catalogue of existing volcanos. This makes the information rather scattered, and any one who wishes to become possessed of the whole history of a particular mountain, after he has read the account in the first Appendix, has to search through the list in the second for the records of subsequent eruptions. The other new objects discussed are the igneous fluidity of the interior of the globe, the true character of lavas, the coincidence of volcanic and atmospheric disturbance and tidal action, the foliation of the (so-called) metamorphic crystalline rocks, and the ratio of development of subterranean forces. In the first case our author decides against internal fluidity, and in favour of the origin of disturbance at comparatively small depths. He is inclined to think that lavas in their most molten condition are not homogeneous masses, but include most of the crystals to be afterwards found in them in a state of mechanical mixture in their more fluid materials, and that their fluidity is attributable to a certain extent to the presence of interstitial water. The difference of barometric pressure is adduced as one cause among others of the variation of eruptive activity, since the boiling-point of water, which takes such a large share in these phenomena, is in this way changed. There appears to be no evidence in favour of greater activity of volcanos in former ages than at present, though their action at no time has been regular, rhythmical, or capable of being reduced to an average. Our author therefore sides rather with the Uniformitarians than with the Evolutionists, and he even goes so far as to see no geological reason that would point to a gradual cooling down of the planet.

Reports on Observations of the Total Solar Eclipse of December 22, 1870. Conducted under the Direction of Rear-Admiral B. F. SANDS, U.S.N., &c. Washington: Government Printing Office. 1871.

WE may without offence hope that the United States Navy may never be worse employed than it was in the case of the expedition of which the Report is now before us. The claims of hospitality to the scientific men from the other side of the Atlantic, for which several of the writers in this volume make grateful acknowledgments, we shall ever be willing to liquidate: these claims can never be so great that we shall not be anxious to repay them with interest.

In the present volume we have the reports of the observations of Professor Simon Newcombe, at Gibraltar; and Professors Asaph Hall, Wiliam Harkness, and J. R. Eastman, at Syracuse; and a letter from Capt. Tupman, of the Royal Marine Artillery, accompanied by sketches. Professor Newcombe made his observations from Buena Vista, a point about midway between Europa Point and the town of Gibraltar, and about twenty miles from the line of central eclipse. He enjoyed a fairly clear sky during the period of totality, but was disappointed in the brilliancy of the corona.

Professor Hall was on one of the bastians of the town of Syracuse. He paid most attention to the corona, and though, as in the former case, previously the clouds had impeded the view during totality, he was able to make the required observations. An adjoining spot was occupied by Professor Harkness, whose observations were principally with the polariscope, and with the assistance of Capt. Tupman he also used the spectroscope to the corona. Professor Eastman was about forty yards from the former party. With the assistance of his wife he intended to make observations with a clinometer polariscope (on moon, sky, and corona) and photometer; he was, however, unsuccessful with the latter.

The whole of the reports are exceedingly interesting and well worth reading, though in one or two places they betray by their language their American origin.

A Vision of Creation. A Poem. By CUTHBERT COLLINGWOOD, M.A. and M.B., Oxon, &c. With an Introduction, Geological and Critical. London: Longmans. 1872.

IT is not our custom to review poetry, and even in this case we shall have but little to say about the literary value of Mr. Collingwood's work; it is the geological introduction which induces us to notice the poem. The key to the title will occur to everyone who has read Hugh Miller's "Testimony of the Rocks." A seer such as existed among the Jews before the Prophets of later date displaced them—a seer of visions in a patriarchal age—whether Moses himself or some earlier worthy, is left undecided, is visited by a heavenly messenger, who is commissioned to communicate to him the mysteries of the origin of the universe, but who first draws his attention to the physical phenomena surrounding him, and describes how man shall in after ages learn for himself from the records around him how the world came into existence. This angelic being then conveys the seer to a desolate region, and presents to his eyes visions of the early condition of the world when emerging from its primeval chaos into the full perfection of its present condition, and these visions are accompanied with an explanation of the events as they take place. The words of the Book of Genesis are used as an outline, which is filled in by the light of modern science. Thus the beginning is made to answer to the period anterior to all geological record and to be suggestive of the Nebular Hypothesis. The earth, "without form and void," corresponds to the Azoic age of igneous rocks. This state of chaos the seer describes as "a world, yet not a world," for which the Greek is given, and a reference is added to Genesis i., 2., leading one to suppose that this is the Septuagint version of that verse, which is misleading. The creation of light is made simultaneous with the so-called metamorphic rocks of the Laurentian and Cambrian series. The first appearance of a firmament or atmosphere is the period of the Silurian rocks formed beneath a shallow sea of almost universal extent. The appearance of dry land characterises the Devonian period, in which the old red sandstone produces mosses, &c., whilst vegetation of marked type, both "herb" and "fruit-tree," have left their record in the carboniferous strata. The appearance of sun and moon, already created, but until now hidden by dense mists, denote the introduction of a new era, and the new red sandstone accordingly marks the beginning of the secondary rocks, and lies between the vegetation and the reptiles of the next age.

These are the "sea monsters," "the moving creature that hath life," the huge Saurians of the Lias and Oolite. The "fowl" in the expanse of heaven are first found in the Upper Oolite, but it is scarcely so clear as the author would make out that the birds were numerous in the period of the chalk. Perhaps we should scarcely look for the remains of birds at the bottom of a deep sea, and we hardly know what may have been the contemporaneous land. The sixth day describes in the Meiocene times the creation the huge mammals of the pachydermatous genus, whilst man follows all in a period still antecedent to the present "seventh day," in which the present order of things continues mostly unchanged under a reign of law. All this is told pleasantly in flowing blank verse, which rather weakly challenges comparison with Milton.

Dr. Pereira's Elements of Materia Medica and Therapeutics. Abridged and Adapted for the Use of Medical and Pharmaceutical Practitioners and Students, and Comprising all the Medicines of the British Pharmacopœia, with such others as are Frequently Ordered in Prescriptions or Required by the Physician. Edited by ROBERT BENTLEY, M.R.C.S., F.L.S., and THEOPHILUS REDWOOD, Ph.D., F.C.S. London: Longmans, Green, and Co.

THIS abridgment of Dr. Pereira's great work will be welcomed both by medical and pharmaceutical students. The original work, valuable as it was, contained much matter which was not required by the student, and its great bulk rendered it too expensive for many to possess it. In 1865, Dr. Farre, Professor Bentley, and the late Robert Warington, prepared an abridgment which came within the reach of all, and which was certainly a most useful book, the appearance of the "British Pharmacopœia," however, and the rapid progress of the science of Materia Medica, rendered another edition necessary, and we are glad that its preparation was entrusted to such competent men as Professors Bentley and Redwood. The medicines described comprise in addition to those of the "British Pharmacopœia," many remedies frequently ordered by medical practitioners, and more space might with advantage have been allotted to some of these remedies, the information in some instances being, we think, insufficient for the student. The first part of the work is devoted to the new system of chemical notation (the symbols and atomic weights being given according to both the old and new systems); a description of medicines derived from the mineral kingdom and definite chemical compounds, organic as well as inorganic, which are obtained as products of decomposition. The second part embraces medicines derived from the vegetable kingdom, including bodies of definite chemical composition obtained as educts from vegetable substances, and here the latest discoveries are introduced. In the third division a description is given of medicines derived from the animal kingdom, including bodies of definite chemical composition obtained as educts from animal substances.

In studying Materia Medica much assistance is gained from good illustrations. We remember well the good we derived in our own studies from Stephenson and Churchill's valuable work on "Medical Botany;" but as this work is far too scarce for many students to possess a copy, we shall be glad, in a future edition of the work before us, to see engravings of all the more important plants, &c., instead of so many references to plates in scarce or expensive works on Medical Botany, which, in most cases can only be consulted at the Pharmaceutical or Medical Libraries.

This abridgment of Dr. Pereira's excellent work reflects the greatest credit on its Editors, and we commend it to the student of medicine and pharmacy as a necessary companion when preparing for examination.

Official Handbook to the Marine Aquarium of the Crystal Palace Aquarium Company. By W. A. Lloyd, Superintendent of the Aquarium. Second Edition. 1872. Pp. 64.

It is not often that the guide book of a public exhibition comes under the notice of the reviewer, such publications in the majority of instances being mere catalogues, and but rarely possessing any scientific interest. The present little book is, however, an agreeable exception.

After explaining the arrangement and general contents of the thirty-eight tanks comprised in the public portion of the aquarium, the author devotes twenty-nine pages to the history of the Marine Aquarium. Among the earliest notices is the following quaint extract from Pepys's Diary:—"Thence to see my Lady Pen, where my wife and I were shown a fine rarity; of fishes kept in a glass of water, that will live so for ever—and finely marked they are being foreign." The experiments of Madame Power, the late Dr. N. B. Ward, Dr. George Johnston, and Sir John Graham Dalyell, are described. These are followed by an account of the first entirely successful marine aquaria, the simultaneous results of the trials of the late Robert Warington and Mr. P. H. Gosse, F.R.S. Then follows an account of the various public aquaria, commencing with that of the Zoological Society, and describing most of those at home and on the Continent. The principles necessary to the maintenance of unchanged sea-water in a condition fit for the support of animal life are discussed at some length, and a detailed account given of the contrivances employed at the

Crystal Palace. Mr. Lloyd justly places the greatest reliance on constant circulation of the sea-water in the tanks; this is effected by a steam engine and suitable pump, both in duplicate to provide for accidents, capable of forcing from 5000 to 7000 gallons per hour through the range of tanks.

Nearly the whole of the pipes, strainers, and other apparatus, including the pumps, are made of vulcanite, which has been found effectually to resist the action of sea-water, the only exception being some of the larger pipes, which are of stoneware.

Pages 38 to 64 are devoted to a brief and popular, but by no means unscientific, account of the various animals kept in the tanks. These are arranged according to their classes. Many interesting facts relating to the habits of these creatures are here given, much of which is derived from the author's personal experience in aquaria both at home and abroad.

The publication of this little work is a step in the right direction, and Mr. Lloyd is to be congratulated on having produced a guide quite equal in its own department to the admirable ones of the Royal Gardens and Museums at Kew.

Astronomy and Geology Compared. By LORD ORMATHWAITE. London: John Murray. 1872.

The Origin of Species by Means of Natural Selection. By CHARLES DARWIN, M.A., F.R.S., &c. Sixth Edition, with Additions and Corrections. Eleventh Thousand. London: John Murray. 1872.

Man in the Past, Present, and Future. From the German of Dr. L. Büchner. By W. S. DALLAS, F.L.S. London: Asher and Co. 1872.

THE title of Lord Ormathwaite's work is that of the first Essay, in which the evidence afforded by Astronomy and Geology are compared with the view to ascertain the value of that of the latter science. The third Essay treats of progress and civilisation. The author's thoughts are throughout clearly expressed; and there is little need to tell the reader that under the affliction of extreme dimness of sight an amanuensis has been employed. The second Essay entitled, "Remarks on the Theories of Mr. Darwin and Mr. Buckle," gives the points on which Lord Ormathwaite is at issue with Mr. Darwin, Mr. Buckle receiving but little consideration. Strangely, one of the chief objections to Mr. Darwin's theory is answered by an addition to "The Origin of Species" in the present edition, both works being published at the same time. We quote the reply, because the argument is one often advanced against the theory of the mutability of species. "But as my conclusions have lately been much misrepresented," says Mr. Darwin, "and it has been stated that I attribute the modification of species exclusively to natural selection, I may be permitted to remark that in the first edition of this work, and subsequently, I placed in a most conspicuous position—namely, at the close of the Introduction—the following words:—'I am convinced that natural selection has been the main but not the exclusive means of modification.' This has been of no avail. Great is the power of steady misrepresentation; but the history of science shows that fortunately this power does not long endure. It can hardly be supposed that a false theory would explain in so satisfactory a manner as does the theory of natural selection the several large classes of facts above specified. It has recently been suggested that this is an unsafe method of arguing; but it is a method used in judging of the common events of life, and has often been used by the greatest natural philosophers. The undulatory theory of light has thus been arrived at; and the belief in the revolution of the earth on its own axis was until lately supported by hardly any direct evidence. It is no valid objection that science as yet throws no light on the far higher problem of the essence or origin of life. Who can explain what is the essence of the attraction of gravity? No one now objects to following out the results consequent on this unknown element of attraction; notwithstanding that Liebnitz formerly accused Newton of introducing 'occult qualities and miracles into philosophy.'"

I see no good reason why the views given in this volume should shock the religious feelings of any one. It is satisfactory, as showing how transient such impressions are, to remember that the greatest discovery ever made by man, namely, the law of the attraction of gravity, was also attacked by Leibnitz, "as subversive of natural, and inferentially of revealed religion." A celebrated author and divine has written to me that "he has gradually learnt to see that it is just as noble a conception of the Deity as to believe that He required a fresh act of creation to supply the voids caused by the action of His laws." This quotation not only answers Lord Ormathwaite's objection, but it also removes the obstacle to the reception of the Darwinian theory by the most timorous in acknowledging the advancement of scientific inquiry. It may be said to be the chief addition, as it is that embodying the widest principle; the remaining corrigenda relate to natural science particularly, and are further evidence in support of the theory.

Dr. Büchner divides his work under three heads: "Our Origin;" "What are We?" "Whither are we Going?" In considering the origin of man, the author very carefully brings to the surface all the geological proofs of man's antiquity, buried to the general reader in almost inaccessible works. The method of the arrangement is admirable. "What are we?" cannot strictly be said to follow the Darwinian theory of evolution, because Dr. Büchner's lectures were delivered before Mr. Darwin's "Descent of Man" was known in Germany; but the following obtains in the superior evidence brought forward by Mr. Darwin. Dr. Büchner has answered the preceding questions; but the next he proposes, "Whither are we going?"—we must agree with his translator, Mr. W. S. Dallas, F.L.S., in saying that we do not arrive at the same conclusions. Man, Dr. Büchner, who is a thorough materialist, considers to be immortal, to the extent that the living principle which animates the material form is transmutable, and, following the doctrine of the conservation of energy, is never removed from this world, being absorbed by other, on the decay of the present material; thus it is form only that suffers change. From this basis it would appear that man is to go on improving until the struggle for the means of existence becomes a struggle for existence itself, guided by a fully developed intellect. Then the author proceeds to depict this mundane paradise, governed by a republic, possessing no restrictions as to private property, the restoration periodically of capital to the community. In spite of this philosophical Hades to which we are to be consigned, it is certainly comforting to know that we are not an animal system to be developed by-and-bye into a yet more perfect organisation; but that the advance we make in this present life will benefit us when we become somebody or something else, or a portion of several somebodies or somethings else. Seriously, while admiring the logical continuity of the first sections of the work, it must be said that the last portion is liable to cause the condemnation by many of the entire work. So far from being the opinion that the theory of evolution logically results in utter materialism, Professor Huxley has just said in the "Fortnightly Review," that "personally he was not a materialist, but, on the contrary, believed that materialism contained grave philosophic error." And Professor Huxley is not only a naturalist second to none, but an enthusiastic advocate of Darwinism. We recommend the books collectively and individually to our readers.

A Manual of Zoology for the Use of Students. With a General Introduction on the Principles of Zoology. By H. ALLEYNE NICHOLSON, M.D., D.Sc., &c., Professor of Natural History and Botany in University College, Toronto, &c. Second Edition. Edinburgh and London: W. Blackwood and Sons. 1871.

ONLY six months ago we noticed the first edition of this work as fulfilling a want in our series of text-books. That there were many to whom this work has proved acceptable is evidenced by the early issue of this second edition. The author has taken advantage of the opportunity to make many additions, the plan of classification still being based essentially upon the views put forth by Professor Huxley. Every care has been taken to render the work self-explanatory. An admirable glossary is appended; the book being, indeed, the best hand-book on the subject.

Introduction to the Study of Biology. By H. ALLEYNE NICHOLSON, M.D., D.Sc., M.A., Ph.D., F.R.S.E., F.G.S., &c., Professor of Natural History and Botany in University College, Toronto. Edinburgh and London: William Blackwood and Sons. 1872.

THIS little work is something more than a school-book. It is based chiefly upon the Introduction to Dr. Nicholson's "Manual of Zoology." We commend it for the concise description of the several biological theories, their errors and agreements. The book is well enough bound to form a useful and a handsome present.

The Earth's Crust. A Handy Outline of Geology. By DAVID PAGE, LL.D., F.G.S., Professor of Geology in the College of Physical Science, Newcastle-on-Tyne—University of Durham. Sixth Edition. Edinburgh and London: William Blackwood and Sons. 1872.

THIS is another edition of Dr. Page's Outline-sketch of Geology, now sometime out of print. It forms one of Messrs. Blackwood's Natural Science Series; and is admirably suited to the student attending elementary lectures on geology.

Science Primers. II. *Chemistry.* By H. E. ROSCOE, Professor of Chemistry in Owen's College, Manchester; Author of "The Spectrum Analysis," "Lessons in Elementary Chemistry," &c. III. *Physics.* By BALFOUR STEWART, Professor of Natural Philosophy, Owen's College, Manchester; Author of "Elementary Lessons in Physics." London and New York: Macmillan and Co. 1872.

IN publishing these elementary works on Chemistry and Physics, "the object of the authors has been to state the fundamental principles of their respective sciences in a manner suited to pupils of an early age." Notwithstanding the difficulty of describing in simple language experiments really scientific in their nature, we need scarcely say Professors Roscoe and Stewart have been eminently successful. They have accomplished their object in a manner new to elementary treatises, that of teaching by direct experiment. Nothing is advanced in either of these little works that is not proved by a simple experiment. It ought to be said that the teaching follows the experiment, the young pupils accompanying the teacher as assistants in the exploration of the truths concealed by Nature. Chemistry and Physics in the Science Primers are taught, certainly as they ought to be, not as mathematical demonstrations, but as experimental sciences. We do not hesitate to say that a Science Primer will soon be found in every satchel. But these little books can be viewed in another light: they show that the method of instruction, scientific more particularly, pursued by a Continental nation celebrated for its technical training, is being followed and improved upon by our own schools. We may thus regard them as signs of prolonged national success.

An Elementary Treatise on Curve Tracing. By PERCIVAL FROST, M.A., Formerly Fellow of St. John's College, Cambridge; Mathematical Lecturer of King's College. London: Macmillan and Co. 1872.

THIS treatise requires, for its successful reading, only a slight familiarity with the higher branches of algebra, and is, indeed, an intellectual pleasure-ground for the student of moderate mathematical attainments. The arrangement is in well-ordered sequence.

A Treatise on the Theory of Friction. By JOHN H. JELLETT, B.D., Senior Fellow of Trinity College, Dublin; President of the Royal Irish Academy. London: Macmillan and Co. Dublin: Hodges and Co. 1872.

MR. JELLETT has been the first to remove the theory of friction from the trammels to which it was subject as a department of applied mechanics, and to give it a new standing purely mathematical. Such an endeavour is worthy of the highest encomium, because we derive not only a subject rich in material for mental labour, but are likely to arrive at improved construction of mechanical appliances. It might be said to be an ascent from rule to principle. To the mathematician, as well as to the engineer, this work will be of the highest interest.

A New Star Atlas for the Library, the School, and the Observatory. By RICHARD A. PROCTOR, B.A. Camb., F.R.A.S.; Author of "The Sun," "Other Worlds than Ours," &c. London: Longmans and Co. 1872.

MR. PROCTOR quotes on his title-page the exclamation of Carlyle, "Why did not somebody teach me the constellations, and make me at home in the starry heavens, which are always overhead, and which I don't half know to this day?" How many before and since these words were penned have had occur to them the self-same thought, have desired a familiar acquaintance individually, as it were, with the members of that celestial system which, as far as we can tell, suffers no decay, and which is the most approximate symbol of eternity. Had the exclamation been uttered now, it is only due to Mr. Proctor to say that it would have lost its point, for most worthily has he filled the post of the "somebody" so pathetically lamented by Carlyle. Anyone who can understand a map can use Mr. Proctor's little Atlas. There are twelve maps, each exhibiting a tenth part of the heavens. No pains have been spared to clear the maps of all which could cause confusion to the beginner; but this has been done in such a way that the more advanced student will find nothing wanting. We cannot enter into detail here; but those accustomed to the use of astronomical maps will admit the clearness of this Atlas when we say that α and β Andromedæ are separate 1·25 inches. Not the least interesting portion of the book to the general reader will be that devoted to the cursory consideration of the errors some even of our most popular writers have fallen into when describing a scene under a starry sky. The work is intended as a companion to Webb's "Celestial Objects for Common Telescopes," and is, in fact, an epitome of Mr. Proctor's Large Star Atlas, so well known to telescopists. We hope we may soon have to notice a second edition.

Theory of Heat. By J. CLERK MAXWELL, M.A., LL.D. Edin., F.R.SS. L. & E., Professor of Experimental Physics in the University of Cambridge. London: Longmans and Co., 1871. 312 pp., 8vo.

Technical Arithmetic and Mensuration. By CHARLES W. MERRIFIELD, F.R.S., Barrister-at-Law, Principal of the Royal School of Naval Architecture and Marine Engineering, late an Examiner in the Department of Public Education, &c. London: Longmans and Co., 1872. 308 pp., 8vo.

THESE volumes are two of the admirable series of text-books of science, edited by Professor Goodeve, and published by Messrs. Longmans. Perhaps no other series of elementary works can show so many names of eminent men. We take them in the order of publication, and have to notice first Professor Clerk Maxwell's treatise on the theory of heat. The opening chapters are devoted to thermometry, calorimetry, and elementary dynamical principles. Then, upon this basis, Dr. Maxwell proceeds to lay before the student a perfectly systematised and simple explanation of the difficulties likely to be encountered in pursuing the study of the present theory of heat. There are necessarily some mathematical formulæ introduced into the work, but these are of the simplest kind, and present not the slightest obstacle even to an ordinary reader. The work is turned out with the neatness characteristic of extreme care and of a knowledge of the subject intimate in the highest degree.

The next volume we have the pleasure to notice is that by Mr. Merrifield, the subject being the eminently useful one of technical arithmetic. Technical arithmetic has been, till within the last few years, a very misty affair, the operations being carried on mostly by rule of thumb. This has decidedly not been for the want of published works on the subject, but arises simply from continually treading the same path—rules not principles have been inculcated. Mr. Merrifield reverses the order of things, and teaches principles, leaving the deduction of rules to follow in course. Nowhere is this more evident than in the extraction of roots, a simple formula for the *n*th root being given, and which can be easily remembered. Be it in the treatment of contracted methods of working the ordinary rules, or in elucidating the principles of solids of revolution, the arithmetic is the best we have seen.

Natural Philosophy for General Readers and Young Persons. Translated and Edited from Ganot's "Cours Elémentaire de Physique." By E. Atkinson, Ph.D., F.C.S., Professor of Experimental Science in the Staff College. London: Longmans and Co. 1872.

Dr. Atkinson's translation of Ganot's "Eléments de Physique," the fifth edition of which we recently noticed, is better suited to more advanced pupils, who are capable of mastering the mathematical formulæ it contains. The present work is elementary and abridged of all matter likely to prove too difficult for the junior student. It must be understood that it is not a smaller edition of the "Elementary Treatise on Physics," but a translation of Ganot's "Cours Elémentaire de Physique," a text-book very extensively circulated in France. Dr. Atkinson has made many additions, and at all times very happily. The illustrations are highly praiseworthy; they are far from resembling the linear sketches with which many of our school-books are disfigured, and, indeed, in some instances, are pretty little views. The letterpress is clear. The work is well calculated to take its stand as a text-book of physics for the middle and upper classes of boys' and of girls' schools, and as a familiar account of physical phenomena and laws for the general reader. It will form an admirable hand-book for students studying to matriculate in the London University.

A Manual of Chemical Physiology, including its Points of Contact with Pathology. By J. L. W. Thudichum, M.D. London: Longmans and Co. 1872.

In Dr. Thudichum's experience as a teacher, the printed notes to his "Researches Intended to Promote an Improved Chemical

Identification of Diseases," published in several numbers of the annual "Report of the Medical Officer of the Privy Council," have proved so useful that he has been tempted to submit them to the public. The manual is a complete epitome of physiological or animal chemistry, revised to the latest date; and is well adapted to the requirements of the medical student preparing to meet the examining board. A second part of the work is an analytical guide, devoted to the assistance of those who desire to make themselves practically acquainted with the phenomena and constituents of animal bodies. The work is systematically arranged throughout, and is well illustrated with engravings of the various absorption spectra.

Elements of Chemistry: Theoretical and Practical. By WILLIAM ALLEN MILLER, M.D., D.C.L., LL.D., late Professor of Chemistry in King's College, London. Revised by HERBERT McLEOD, F.C.S., Professor of Experimental Science, Indian Civil Engineering College, Cooper's Hill. Part I. Chemical Physics. Fifth Edition, with Additions. London: Longmans and Co. 1872.

THE call for a new edition of Dr. Miller's "Elements of Chemistry" so soon after the lamented death of the illustrious author is a proof, if any were needed, of the extensive circulation of the work. The additions made by Professor McLeod are chiefly from the Transactions of the learned Societies, and are most carefully selected. In gas-analysis, and many other departments of experimental science, Mr. McLeod is himself a high authority, so that numerous little difficulties are smoothed away. This edition is exceedingly complete.

The Discovery of a New World of Being. By GEORGE THOMSON. London: Longmans and Co. 1871.

THIS is a most surprising work. One is surprised at the first few lines, and afterwards at one-self for being surprised. With the familiarity of an old acquaintance—for there is no preface or introduction—Mr. Thomson commences to address the reader thus:—"In the year 1862 the author commenced to write a series of essays on the Human Mind. Being then unacquainted with the systems either of ancient or of modern philosophy . . ." Just what many are so fond of doing—sitting down to write about a matter of which they know, and have taken the trouble to ascertain, nothing. But then the reader and Mr. Thomson are such old acquaintances—sufficient reason that the reader should be button-holed until the author says, in the last page but one of the book, "We must explain what, and how much, we mean, by entitling this essay—The Discovery of a New World of Being." Surely very little more need be said. If the author could explain his discovery in a page, why does he talk for nearly three hundred? But this is but an additional proof how much is needed an essay on the limits of the use of the imagination. "All the faculties of the mind," says Mr. Thomson, "are only a series of flashes of the imagination." What will next be foisted upon the imagination, that convenient vantage-ground for all that is inexplicable. If the use of the imagination is to preclude good logic, and the ordinary courtesies due to the reader, there will not long be many in its favour. There is, however, some recommendation due to the work; Mr. Thomson has a delicate appreciation of the beauties of our religion.

New Theory of the Figure of the Earth. By WILLIAM OGILBY, M.A., Trin. Coll. Camb., F.G.S., F.Z.S., &c. London: Longmans and Co. 1872.

THE author of this *brochure* presents a new theory of the figure of the earth, considered as a solid of revolution, founded upon the direct employment of the centrifugal force, instead of the common principles of attraction and variable density. Mr. Ogilby thinks mathematicians have not yet succeeded in solving the problem of the figure of the earth, and that they depend too much upon algebraic analysis when reasoning upon physical subjects. He says—"It is high time that mathematicians should moderate these unwarrantable pretensions (the omnipotence of analysis to the exclusion of all other modes of philosophical reasoning), understand that the laws of Nature do not depend on the integration of a differential coefficient, or the solution of a transcendental equation, and learn that there are more secrets in Nature than are comprised in the analytical shibboleth $\frac{d^2v}{dt^2}$."

The purpose is to deprecate the *abuse*, not the *use*, of the science of mathematics, but "to employ it, according to the recommendation of Bacon, and in imitation of Newton, not as the mistress, but as the handmaid, of physics,—not as the maker of the laws of Nature, but as their humble interpreter." With this view Mr. Ogilby sets out, making no hypothesis of any description, nor requiring other data than those which are furnished by observation and experience. Starting from the admitted phenomenon that the earth is a heterogeneous solid, whose mean density, magnitude, and periodic rotation are known quantities, the author proceeds to examine the action of centrifugal force in producing its present figure, determining the law of gravity at its surface, the variation of curvature, the length of the terrestrial axis, and the change of local ellipticity at every point of the surface. The results obtained are definite, and we commend them to the notice of our mathematical readers.

Index of Spectra. By WILLIAM MARSHALL WATTS, D.Sc., Senior Physical Science Master in the Manchester Grammar School. With a Preface by H. E. ROSCOE, B.A., Ph.D., F.R.S., Professor of Chemistry in Owen's College, Manchester. London: Henry Gillman. 1872.

DR. ROSCOE, in the preface, alludes to the inconvenience arising from the employment of different scales in mapping spectra. Spectroscopists generally will agree with him. Nothing is more annoying than to find, after collecting the measurements scattered through many volumes, that before the measures are comparable they must be reduced to a common standard. This difficulty will no longer exist. Dr. Watts has much facilitated spectroscopic research, by collecting all existing measurements of the spectra of the elements, and presenting them on a uniform scale of wave-lengths, upon the basis of Angström's measurements of the wave-lengths of the principal Fraünhofer lines. This basis is without doubt the most accurate, for Angström's measurements are so very exact that it is unlikely that any corrections which may be rendered necessary by new and more exact measurements will affect them, except in the decimal place. Besides Angström's numbers, however, Dr. Watts gives those obtained by Fraünhofer, Ditscheiner, Bernard, Van de Willigen, Mascart, and Esselbach. Of course we have the mapping of the spectra of the elements by Huggins, Thalén, and Kirchhoff; and where these three *savants* have not endorsed the examination of the spectrum, in each case reference is made to the original memoir. Mascart, Ketteler, and Müller's numbers were obtained by direct observation of the diffraction spectra. The measurements for chlorine, bromine, iodine, phosphorus, sulphur, selenium, nitrogen, and oxygen, are those by Plücker, and are reduced to wave-lengths by means of an interpolation curve drawn from the lines of oxygen and nitrogen. The measurements and calculations have been verified, as far as possible, by Dr. Watts, upon his own spectroscope, while twenty-eight of the results are checked by comparison with those of Dr. Gibbs. The numerical results are well assisted by the graphic illustrations, in which, on Bunsen's plan, the intensity of the line is indicated by the height. A complete set of chromolithographs, of the double spectra of nitrogen, sulphur, and carbon, is appended. Besides the method of graphic interpolation, Dr. Gibbs's interpolation and extrapolation formulæ have been given, with simple and clearly-explained examples. We are sure that every spectroscopist will agree with us when we say, sincerely is Dr. Watts to be thanked for the laborious task he has undertaken. His work needs no recommendation; it will be, if it has not already been, placed on the shelves of every scientific library. It should be known that the scale of wave-lengths adopted is applicable to spectroscopes of all sizes; there is consequently no difficulty in its universal application.

Index to Gmelin's Handbook of Chemistry. By HENRY WATTS, B.A., F.R.S., F.C.S., Editor of the "Journal of the Chemical Society." London: Harrison. 1872.

THE last volume of this important chemical work has now been offered to the public. To chemists, and to all interested in chemical manufactures, the value of Gmelin's "Handbook" is incomparable; and it is due to us to make known to those intending to complete the set of these volumes that the earlier volumes are becoming scarce, and that early application will be needed to possess those remaining. Subscribers who have paid their subscription for the year 1864 will have forwarded to them the Index and the concluding (eighteenth) volume. The Index is very copious, reference being made to volume and page. Every subject is included under as many heads as possible. It is entirely unnecessary to recommend the work.

The Year-Book of Facts in Science and Art. By JOHN TIMBS, Author of "Curiosities of Science," &c. London: Lockwood and Co. 1872.

THIS IS a well-arranged digest of the most important discoveries and improvements of the past year. The title-page is faced with a clear engraving from a photograph of Sir W. Thomson, F.R.S.

Elementary Natural Philosophy. Being a Course of Nine Lectures, specially adapted for the use of Schools and Junior Students. By J. CLIFTON WARD, F.G.S., Associate of the Royal School of Mines; of Her Majesty's Geological Survey. London: Trübner and Co. 1871. 215 pp., 8vo.

THIS little book is evidently intended to serve a double purpose, as a handbook for the very young student, and as an aid to the schoolmaster who may wish to introduce the study of elementary physics into his curriculum. It contains the latest experiments likely to answer the end in view. The work is altogether very praiseworthy.

PROGRESS IN SCIENCE.

MINING.

It has often been remarked that the occurrence of colliery explosions is closely connected with certain states of the weather. A valuable paper on this subject has been read before the Royal Society by Mr. R. H. Scott, F.R.S., the Director of the Meteorological Office, and Mr. W. Galloway. After reviewing the evidence bearing upon this subject, the authors conclude that we are quite justified in maintaining that certain meteorological changes are proximately the cause of most of the accidents in our coal mines. The continuous records kept at Stonyhurst Observatory furnished the meteorological data used in this enquiry. Curves for the barometer and thermometer were plotted for the three years extending from 1868 to 1870, while records of the colliery explosions during the same period were obtained from the Government Inspectors, either directly or from their published reports. On comparing the actual dates of the explosions with the corresponding meteorological records, it was found that out of 550 explosions 266 might be attributed to the state of the barometer, and 123 to that of the thermometer, while the remaining 161 remained unaccounted for on meteorological grounds. In other words, exactly 70 per cent of the explosions were directly related to meteorological influences. Some of the authors' conclusions are of much practical value. Thus, they show that we must not always expect an accident to follow immediately after a fall of the barometer, but that in many cases explosions have not occurred until two or three days after the barometric column had reached its minimum. It appears that during violent oscillations of the barometer the number of explosions does not correspond to the number of minima, but the greatest number of accidents occur when a serious break follows a long period of fair weather. Elevation of temperature must, of course, greatly interfere with the natural ventilation of a colliery; and hence, if a warm day occur in a cold season, when natural ventilation is relied upon, it is very likely to be followed by an explosion. For a like reason, the first hot days of spring are too often marked by colliery accidents.

A paper on increased safety in working coal was read by Mr. S. Firth, M.A., at a recent meeting of the Midland Institute of Mining Engineers. By carefully comparing the dangers incident to the present systems of working by "bord and pillar" and by "long wall," the author concludes that the latter is by far the safer method. But although advantageous in many respects, the long-wall system exposes the collier to considerable danger from falls of the roof, from falls of coal, and from the use of gunpowder. Now, Mr. Firth argues that these sources of peril may be almost entirely removed if coal-cutting machinery be employed in connection with long-wall work: the miner is then no longer exposed to danger by falls of coal, the roof is much safer, and no powder is required. Hence the author advocates the adoption of the long-wall system coupled with the use of coal-cutting machinery, and believes that the danger of colliery work will then be limited to such items as could be readily held in check by strict attention to the Government rules. To use the author's words, it may thus become "possible for miners to work and win coal without the operation being a perpetual fight for life."

To encourage inventors in improving coal-cutting machinery, Mr. Firth has liberally offered a prize of £500 for the machine which shall be best adapted for general use in coal and ironstone mines, and shall reduce manual labour to a minimum. The machines entered for competition are to work with compressed air supplied at a pressure of 50 lbs. to the square inch. It is hoped that this stimulus will lead to great improvements in coal-cutting machines, and that the miner will thus eventually be relieved of one of the most fatiguing and dangerous branches of his work.

An improved form of safety-lamp, which appears to offer considerable advantages, has been constructed by Mr. H. D. Plimsoll. At the base of the lamp is an air-chamber in form of a truncated cone, the upper rim of which closely surrounds the wick of the lamp. The bulk of this cone is occupied by the oil-reservoir, and the space between the outside of this vessel and the inner wall of the conical cavity is reduced to a width of about one-eighth of an inch. Air is admitted to this chamber through very minute orifices in a metal plate, and passes through the narrow space to the wick. The brilliant light thus obtained is not dimmed by any cage of wire-gauze, for the flame is merely surrounded by a cylinder of thick glass. Should any fire-damp enter the lamp, the quantity is said to be too small to break the glass by its explosion. The flame cannot be communicated to the exterior, as it is cooled down by the metal walls of the narrow air-chamber, while the explosion inside the lamp at once extinguishes the flame, and thus prevents the lamp becoming red-hot. If the air be very dangerous, Mr. Plimsoll cuts off all communication with the outside, and connects the air-chamber of his lamp with a reservoir of pure air, and as soon as this supply is exhausted the lamp is necessarily extinguished. As the light is brilliant there is not much temptation for the miner to unscrew the top; but should he do so, a self-extinguishing arrangement comes into play and effectually thwarts his object.

Air-compressing machinery has of late been very successfully applied to underground haulage and ventilation at the Ryhope Colliery, in Durham; and a valuable description of the machinery, by Mr. W. N. Taylor, has been published, with ample illustrations, in a recent number of the "Transactions of the North of England Institute of Mining Engineers." The moving power is a 150 horse-power steam-engine, with two horizontal cylinders, each 32 inches in diameter, and having a 5-foot stroke. This engine is placed at the surface, and works two air-compressing cylinders, each 33 inches in diameter, with a stroke of 5 feet, directly connected with the piston-rods of the steam-cylinders. The air, after passing through four receivers, is finally conveyed to a double hauling engine with two cylinders, 14 inches in diameter, and working with a stroke of 18 inches. This engine is placed underground, and effects the haulage by means of a rope-drum with spur-gear. A large and economical power is thus available underground, and can be readily directed to any part of the workings; manual labour in hewing and putting the coals may in this way be readily superseded. The compressed air is also a valuable ventilating agent, freeing any working-place from gas, and lowering the temperature of the workings so that our deep mines may be wrought with much more convenience to the men and profit to the owners.

It has long been held by Mr. Godwin-Austen, Mr. Prestwich, and some other distinguished geologists—although staunchly opposed by the late Sir R. I. Murchison—that coal-bearing rocks may exist at comparatively moderate depths beneath the newer rocks in the south-east of England. To decide this point an experimental boring is about to be undertaken in the Wealden area. The spot selected for the experiment is at Archer's Wood, near Battle, the property of Lord Ashburnham, who has nobly given the site, and has further aided the undertaking by a liberal subscription. This boring will prove by actual experiment what are the characters and thickness of the strata immediately beneath the Ashburnham beds, or the lowest series of the Wealden formation, in Kent and Sussex. At the same time it will decide whether palæozoic rocks can be reached, at this locality, within a depth of 2000 feet; and, finally, whether the carboniferous strata of Belgium and North-Eastern France extend across the Channel, as has been suggested, and are continuous with some of our western coal-fields. The care of this scientific undertaking, which is one of great national importance, is entrusted to a committee of some of our most eminent geologists, and the work will be commenced at once, so that something may be done before the British Association visits Brighton. A subscription-list has been opened, and large sums have already been subscribed. Should productive coal-beds be discovered at moderate depths, it seems likely that the social aspect of south-eastern England would be completely changed, and agriculture give way to mining.

At a recent meeting of the Institution of Civil Engineers, Mr. E. Bainbridge read a paper explaining the ingenious method of sinking shafts through water-bearing ground without the use of pumping machinery, as brought into practice by Messrs. Kind and Chaudron. As the method was fully explained in our chronicles last January, when noticing a paper read in the North by Mr. W. W. Smyth, it seems unnecessary to refer again to the subject in this place.

All who are interested in the welfare of our West of England metal-miners must take deep interest in the progress of the Miners' Association of Cornwall and Devon. Each year this association issues a neat little report; and last year's report, which is now before us, is not less interesting than its predecessors. In addition to several short papers of local interest, Mr. J. H. Collins offers some remarks on the successive Mining Schools of Cornwall, in which he traces the history of the several schemes which have from time to time been projected for offering technical instruction to the Cornish miner. The last and only enduring scheme is that which set afoot the present Miners' Association—an institution which was founded in 1859 through the praiseworthy exertions of Mr. Robert Hunt, F.R.S.

METALLURGY.

Although it seems likely that the success of Mr. Danks's rotary furnace will eventually lead to a complete revolution in our system of puddling iron, it is obvious that the general introduction of his furnaces must be a work of much time and great expense. In the meanwhile our ironmasters will no doubt gladly avail themselves of any means of improving our present laborious method of manual puddling without involving any material alterations in their existing plant. Such a method has been lately brought prominently forward by Mr. F. A. Paget, who at the last meeting of the Iron and Steel Institute, and subsequently at the Society of Arts, directed public attention to M. Dormoy's process of puddling with a rotating rabble. The rabble is thrown into rapid revolution by steam-power, while its direction is readily controlled by the hand of the puddler. A revolving shaft above the furnace carries a pulley which is connected by a belt with another pulley below. This lower pulley is secured to the outer end of the rabble, which is thus caused to rotate somewhat in the fashion of the well-known revolving brush used by the hairdresser. By means of a handle jointed to the lower pulley, the puddler readily directs the movements of the rabble. From 300 to 500 revolutions per minute are made by the tool when white pig-iron is treated, and from 800 to 1000 for grey pig. The point of the rabble in the furnace carries a disc which agitates the molten metal, and effectually renews the surface exposed to the air. When the iron "comes to nature," another rabble is used, having, in place of the disc, a short twisted point. Dormoy's method has been successfully employed in Austria and France. It is said that the yield of wrought-iron is increased by at least 30 per cent, while the consumption of fuel is proportionately diminished; that the puddler is relieved of much of his fatigue, although the number of heats in a given time is considerably increased; and, finally, that the phosphorus and sulphur are removed to such an extent from the metal that excellent iron may be obtained from inferior brands of pig. It is right to mention that the rotating rabble, although first brought successfully into actual practice by M. Dormoy, was independently invented and experimentally employed some time ago by Mr. Hutchinson, of the firm of Messrs. Pease, Hutchinson, and Co., of Darlington; but we believe that the results of his experiments, although satisfactory, were never made public.

A rotary puddling machine, recently invented by Messrs. Howson and Thomas, was described by Mr. Howson at the late meeting of the Iron and Steel Institute. This invention is said to be not so much competitive with the Danks furnace as subsidiary thereto. Many of the details of the ordinary puddling furnace are retained, so that the improvements may be adapted, at moderate cost, to the working plant at present in use. The ordinary hearth is replaced by a revolving chamber, of which the best form is that of two cones placed base to base; it is constructed of wrought-iron, with hollow cast-iron trunnions mounted on rollers, which in their turn rest upon a carriage running on wheels in a direction across the axis of the furnace. Motion is imparted by an ordinary engine, and the machine makes from three to eight revolutions per minute. The chamber is protected internally by a lining of bricks of oxide of iron. In order to remove the ball of iron when ready, the chamber is moved from its normal position, and being slightly tilted the ball is readily pushed out through the open trunnions. To avoid cooling the chamber by influx of air through the space formed at the joint of the trunnions—for a certain amount of play must be left to allow for expansion—the opening against which the trunnion works is formed by two cast-iron rings enclosing an annular space, which communicates by a flue or pipe with the space immediately above the fire-grate. By the draught thus produced in the annular space the air which leaks in at the joint is carried off by the most direct route, and consequently little or no air gains admission to the working chamber. This method of checking the ingress of the air is found to be of great importance in the practical working of the machine.

Mr. J. Head, of Middlesbro', has described at some length the Newport puddling furnace, of which a model is exhibited in the International Exhibition. The chief feature of this furnace consists in its economy of fuel. Records of the working show that a given weight of puddled iron may be produced by little more than half the quantity of coal required in the ordinary furnace, while there is also a saving of about 10 per cent of iron. Thus the average consumption per ton of puddled bar was 12 cwts. 3 qrs. 6½ lbs. of coal, and 20 cwts. 2 qrs. 24 lbs. of refined iron; in other words, the puddled bar weighed 96½ per cent of the iron charged. The fettling employed was made in a tap furnace from various cinders and scraps, and contained no hæmatite or other expensive ores.

It is almost needless to mention at this date that the detailed reports on the now celebrated Danks furnace, by Messrs. J. Jones, Snelus, and Lester, were submitted to the Iron and Steel Institute at their last meeting. These reports of the individual commissions supplement the general joint report dispatched from America, and referred to in our Chronicles last quarter. It is gratifying to learn that the high opinion expressed by the Commissioners has been fully borne out by the results which have already attended the working of the furnaces erected on this principle in England. The first of the new furnaces was put up by Messrs. Hopkins, Gilkes, and Co., of Middlesbro', and has worked with great success. In a purely scientific journal we may perhaps be spared the pain of referring at any length to the technical objections which were raised in certain quarters against the validity of Mr. Danks's patent-rights in this country.

Few points in the metallurgy of iron are more important than the elimination of phosphorus from pig-iron containing this prejudicial element. The extent to which it may be removed by the Henderson process is well seen in some determinations recently made by Mr. E. Riley, and published in the "Chemical News" (May 17, p. 237). At a trial made at the Blockhairn Iron Works, in Glasgow, on the 23rd of last December, the charge consisted of 360 lbs. of No. 4 Dalmellington pig-iron, 100 lbs. of ilmenite, 10 lbs. of manganese, and 42 lbs. of fluor-spar. The pig-iron contained 1·14 of phosphorus, but this was eliminated at such a rate that samples of the refined iron taken in succession at thirty, forty, and fifty minutes after fusion contained respectively 0·23, 0·15, and 0·12 of phosphorus. Finally, the phosphorus was so far removed that the wrought-iron contained only 0·07 per cent. On the other hand, the cinder yielded 0·52 per cent. As it was found that all the phosphorus had not passed into the cinder, some of it must have been volatilised during the refining. Samples of bar-iron and plate rolled from iron puddled under

Henderson's treatment, have been tested by Mr. Kirkaldy, and found to stand a very high tensile strain.

At a recent meeting of the Institution of Civil Engineers, Mr. I. Lowthian Bell read an interesting paper on the conditions which favour and those which limit the economy of fuel in the blast-furnace. As iron-smelting consumes nearly one-sixth of all the coal raised in the country, it is important that the highest degree of economy should be practised. Having determined the quantity of heat absorbed in the process of smelting, and the calorific power of the fuel employed, Mr. Bell proceeds to determine the weight of combustible necessary to produce the required effect. Assuming that the ore yields 40 per cent of pig-iron, and requires 15 cwts. of limestone as flux, it will need theoretically about 25½ cwts. of ordinary Durham coke to produce a ton of iron. Mr. Bell discusses the theory of the hot-blast, and believes that its values lies in this principle—that the rate of reduction must not proceed less rapidly than that of fusion. By constructing the furnace sufficiently large the use of hot-blast may be dispensed with, and yet no fuel sacrificed. Beyond a certain limit, however, no advantage is gained by increasing the capacity of the furnace.

Mr. E. F. Mondy has called attention to the magnetic properties of certain copper-slags. Several specimens of ore-furnace slag exhibited strong polarity; those which presented a porphyritic appearance from included fragments of quartz, being more strongly magnetic than a vitreous specimen. Polarity was also evident, though to a less extent, in crystallised metal-slag and in roaster-slag. Feeble magnetism was also exhibited in refinery-slags.

In the April number of the "Journal of the Royal Institution of Cornwall," Mr. J. H. Collins publishes a note on a portion of the incrusted surface of a block of jew's tin found on Trémathack Moor, in the parish of Madron, and recently acquired by the Institution. All ancient blocks of tin pass in the West of England under the name of "Jew's tin," whatever may have been their origin. The block in question was partially coated with a hard, brittle, brown incrustation, which was found to contain 90·62 per cent of binoxide of tin, 1·66 of chloride of tin, 1·04 of peroxide of iron, 0·43 of metallic tin, 0·41 of silica, and the rest of moisture evolved at 120° C.

MINERALOGY.

For a long time mineralogists were acquainted with only a single species of crystallised silica. This was the well-known and ubiquitous mineral—common *Quartz*—a mineral which, as every one knows, crystallises in the hexagonal system, and has a sp. gr, of 2·6. Not long ago Professor Vom Rath showed that silica was dimorphous, and described under the name of *Tridymite* a new species which had a sp. gr. of only 2·3, and yet crystallised in the hexagonal system, but with different parameters from those of quartz. We now learn that silica is trimorphous, for a third form of crystallised silica has been discovered by Professor Nevil Story-Maskelyne, F.R.S. For this new species the name of *Asmanite* is proposed—a name fancifully derived from Asman, the Sanscrit term for the thunderbolt of Indra. Indeed, Asmanite is a meteoric mineral, and was detected among the constituents of the meteorite which was found in 1861 at Breitenbach, in Bohemia, and is now deposited in the British Museum. Asmanite has a low sp. gr. (2·245), and in this point resembles Tridymite, from which it totally differs, however, in crystalline form. Optical examination shows that it is a biaxial mineral, and crystallographic measurements prove that it belongs to the orthorhombic or prismatic system. It is difficult, however, to measure the specimens, for the mineral occurs only in minute grains, more or less rounded, and exhibiting but few crystalline faces. Professor Maskelyne has nevertheless determined the ratios of the parameters of the crystals, and the inclination of the optic axes. Its hardness is 5·5. Two analyses show that it consists essentially of silica, and contains but a small percentage of foreign matter. The Asmanite is associated in the Breitenbach meteorite with enstatite, chromite, troilite or meteoric pyrites, and nickeliferous iron.

Professor Viktor Von Lang has published an account of the crystalline form of *Guarinite*, a mineral resembling sphene. This mineral was described by Guiscardi, who referred it to the tetragonal or pyramidal system; but the author shows that, from the optical characters of specimens in the British Museum, it must be transferred to the rhombic system, although the angles of the crystals and their general habit closely resemble those of a tetragonal mineral. The same distinguished physicist publishes his crystallographic determinations of the form of the rare mineral *Leucophane*.

In examining some of the fine crystals of *cuprite*, or red oxide of copper, from near Liskeard, Professor Schrauf, of Vienna, has detected an icositetrahedron of the value 322, and therefore new to this species.

A note on the occurrence of cobalt in connection with the tin ores of Cornwall has been published by Mr. R. Pearce in the "Journal of the Royal Institution of Cornwall." The author has found cobalt in a sample of tin-stone from Dolcoath Mine, where it probably occurs as an arsenide of cobalt in the mispickel, or white arsenical mundic, associated with the tin. He also finds that the furnace-product known to tin-smelters as "Hard-Head," contains cobalt derived from the tin ore which may have come from different localities. One specimen of hard-head contained 4·4 per cent of cobalt, and Mr. Pearce suggests that its extraction may be profitable, especially if the tin can at the same time be obtained, as the specimen in question yielded as much as 16·25 per cent of tin.

Two new instances of pseudomorphism are recorded in "Poggendorff's Annalen," by M. Helland, of Christiania." One of these is a pseudomorph of mica after garnet from Röstöl, near Arendal, in Norway. The garnet is an iron-alumina variety, rich in manganese, and occurs in small icositetrahedral crystals of a reddish brown colour in a veinstone of pegmatite composed of orthoclase, oligoclase, and mica. Some of the crystals, while retaining their form, have become converted into a green potash-mica. A nucleus of unchanged garnet remains in the centre of some of the partially altered crystals. The second pseudomorph consists of steatite in the form of augite, and occurs at Snarum, not far from the locality which yields the celebrated pseudomorphs of serpentine after olivine.

It has been recently found by Professor Zirkel that the felspathic mineral called *Bytownite*, usually grouped with the lime-soda felspars, so far from being a pure and homogeneous mineral, is made up of at least four distinct constituents. Microscopic sections show that it is really a crypto-crystalline rock containing a triclinic felspar, a green hornblende, a mineral taken to be quartz, and black granules of magnetic iron. Henceforth, then, Bytownite must be expunged from our text-books on mineralogy.

Some experiments on the alteration which felspars suffer by the action of saline solutions and other agents have been made by M. H. Birker and R. Ulbricht, and are of interest as bearing upon the natural weathering and alteration of felspathic minerals. The felspar used contained 8·51 per cent of potash, 3·37 soda, 1·3 baryta, 16·03 alumina, and 65·52 of silica. The action of the several agents was allowed to go on for 2½ years. Distilled water had practically the same solvent action, whether it contained air or not. Carbonate of lime, nitrate of lime, and several other salts exerted but little more action than water alone. Carbonic acid, and carbonate of lime with carbonic acid, increased the action on the alkalies and the silica. Lime-water dissolved more of the felspar by acting on the silica; sulphate of ammonia had an energetic action; but of all the agents used magnesia was found to be the most active.

A set of useful Mineralogical Tables, arranged by Dr. J. Emerson Reynolds, has been published in a recent number of the "Journal of the Royal Dublin Society." Although compiled primarily with a view to facilitate the examination of the fine mineral collection in the possession of the society, these tables admit of much wider use, inasmuch as they contain a considerable amount of general information, and form indeed a concise synopsis of the mineral kingdom. The crystalline system, chemical formula, lustre, colour, hardness, and specific gravity of each species are registered in these tables. In calculating the formulæ, the new atomic weights have been employed, and the quantivalence of the elements marked in most cases. Many of the formulæ are constructed, however, upon an original plan proposed by Dr. Reynolds some time ago, and described in the "Philosophical Magazine." The tables are preceded by an explanatory introduction, indicating the system adopted in the arrangement of the collection, and containing notes on the more interesting species in each group.

The third part of Dr. Schrauf's great work—the "Atlas der Krystall-Formen des Mineralreiches"—has lately been published. This part contains ten plates comprising 160 finely-executed figures of crystals. The species are arranged in alphabetical order, and the crystals figured in the present part extend from "Apophyllite" to "Barytes."

ENGINEERING—CIVIL AND MECHANICAL.

Guns.—We have, on former occasions, recorded the history of the celebrated "Woolwich Infant," as the first 35-ton gun was named. This gun has, since the completion of its proof, remained inactive in front of the butts, not having fired a shot since the trial was made which proved the non-importance of the injury done to its steel lining. Nine other similar guns, completed at the Royal Gun Factories, have since been tested, their proof consisting of three rounds only, viz., two with the ordinary service charge of 110 lbs., and one with the proof charge of 115 lbs. of gunpowder—a more severe strain than they are ever likely to have to endure again.

On the 23rd of March last a paper was read before the Institution of Civil Engineers by Mr. Bashley Britten, "On the Construction of Heavy Artillery, with Reference to Economy of the Mechanical Forces Engaged," wherein it was remarked that so long as nothing definite was known as to the power exerted by gunpowder, the strongest guns were deemed the best. But a good gun was a scientific instrument, which like any other engine, ought to produce the greatest results with the highest economy of means. When the principle of the rifle was applied to cannon, and elongated projectiles were introduced, the skill of engineers soon conquered the difficulty of producing ordnance of ample power to resist high bursting pressure; but this success in the manufacture of strong guns led to the disregard of other considerations of even greater importance, chief amongst which was the use of the strongest powder, which after from 500 to 600 rounds destroyed the interior of the guns by the intense heat and the pressure of the gases. This led to the appointment, in May, 1869, of the Committee on Explosives. From their report, printed in 1870, the following argument was founded. The Woolwich heavy guns were designed for R.L.G. powder, and with it were found to be strong enough to bear all the marginal proofs. The 8-inch guns had to bear a pressure of from 25 to 30 tons per square inch, and the 10-inch guns from 45 to 50 tons per square inch, from the service charges; but henceforth, with pebble powder, the pressure would never exceed about 15 tons in the former and 20 tons in the latter case, as no benefit would be derived from a higher pressure. The principles represented in the designs of the Woolwich system of ordnance were examined under the following heads, viz.:—(1) the quality of the material used; and (2) the power of the charge; and it was argued that with the use of pebble-powder cast-iron might be used with perfect propriety for the exterior of ordnance, at a saving of at least 50 per cent of the cost of the new guns even of the present type. A comparison was then entered into with reference to the proportion which the bore should bear to the length of the gun, small bores and long chases being preferred on account of the greater amount of expansion that would be utilised from the explosion of the powder charge under such conditions.

On the 17th of May last Commander W. Dawson, R.N., read a paper before a meeting of the officers of the two services, at Portsmouth Dockyard, upon the "Seven-Inch Gun." This paper related exclusively to the system of rifling adopted in the manufacture of ordnance at the present day. After tracing the history of the introduction of rifling cannon in this country, the author then gave the results of certain competitive trials which took place in 1863, and after describing the simplicity of the Scott centreing iron-bearing projectile, and the peculiarities of its construction, it was observed that the distribution of strain and the perfect centreing in the bore fully accounted for the grooves of the Scott gun having been as perfect at the end of the competition as when the gun left the factory. It also explained why the centreing shot of the same weight, fired with similar charges, escaped out of its gun so much more readily than the French or Woolwich one, striking a far more heavy blow. The relative merits of the uniform and increasing spiral were then dwelt upon, and the superiority of the former system most conclusively proved by reference to the results of actual experiment. It was shown that the stud system of centreing was ill-adapted for any rapid twist of spiral, and it was stated that the question of long-bearing centreing projectiles *versus* the short-bearing non-centreing system was now under consideration.

Torpedos.—A very interesting paper was recently read by Mr. C. W. Merrifield, F.R.S., before the Institute of Naval Architects, on "Torpedo Warfare," the main consideration being as to how a vessel may best be constructed with a view to defending it from the action of torpedos: the one great principle advocated by Mr. Merrifield being that of sub-division. Extending armour plates over the bottom of a vessel, whilst it would add considerably to its displacement, would not afford any sure means of defence; for approaching a coast known to be protected by torpedos, a number of small ironclads were preferable to one large one, as in the event of a serious accident the loss in life as well as in material would be less. Again, these vessels should be absolutely subdivided into compartments, with air-tight coverings, so that in the event of an accident to one compartment, the water might be driven out by means of pumping air into it. In order to neutralise the effect of the blow given by the explosion of a torpedo, the author proposes that the bottoms of vessels should be constructed with double cells, the lower one being filled with water, which, acting as a buffer, would distribute the blow of concussion and render it less injurious to the fabric of the vessel; the upper cells should be connected by means of pipes and stop-cocks with an air-pump, so that in the event of the middle skin becoming broken the upper cell would be cleared of water by means of a "plenum."

Sewage of Paris.—Our neighbours across the Channel, no less than ourselves, are engaged in the consideration of that most important of all sanitary questions, viz., how best to dispose of town sewage. The Paris sewers at present discharge themselves into the Seine at Clichy and St. Denis, by two principal outfalls, giving a daily discharge of 8,850,000 cubic feet, which affects the water of that river in three different ways. The sand and mud are deposited near the outfall of the two collectors, and the volume of the deposits reach the amount of 3½ millions of cubic feet a year; they produce fermentation in the warm weather, and it is necessary to dredge constantly at a yearly cost of about £8000. The light mud and organic matters rest on the surface of the river and pollute the water for a considerable distance, and the soluble matters produce serious impurities. Since 1867 experiments have been going on, first at Clichy, and subsequently at Grenvilliers, for the purification of the sewage waters with sulphate of alumina, and for utilising them for fertilising purposes. The Conseil des Ponts et Chaussées now, after recommending a complete dredging of the Seine, state that the experiments made at Grenvilliers having given satisfactory results as to the disinfecting the sewage water by their application to irrigation, and by their purification with sulphate of alumina, and these results being such that, if they were known to have a durable efficacy, they would prevent the discharge into the Seine of the impure sewage water, they counsel the Municipal Administration to continue and to develop these experiments. The Prefect has now submitted for the approbation of the Municipal Council a project which will, however, only deal with less than a third of the Paris sewers, but will form a part of the complete scheme. Should the work be undertaken we hope to be able to give further particulars regarding it it in a future number.

Clifton Tunnel.—This tunnel, which will be about one mile in length, is being constructed with the view of affording railway communication between Bristol and the new docks now in course of construction at Avonmouth. The tunnel will be straight, and on an incline of 1 in 64 throughout its length. The tunnel is being bored from each end, and, no water having been met with, the working down hill is just as easy as working up hill. A top heading is being constructed about 10 feet wide and 8 feet high, and the widening out of the tunnel is being carried on at some distance behind, the face of the full-sized tunnel being generally about 30 yards behind the face of the heading. One of Captain Beaument's diamond drilling-machines is being used for boring holes in the face of the heading, the rock being removed by blasting. The enlargement of the tunnel to the full size necessary is done by hand labour in the usual manner. The holes which are bored by the drills are about 2¼ inches in diameter, having a core of 1⅛ inches in diameter, and from 3 feet to 3 feet 6 inches deep. The core is easily removed, and the hole is then left beautifully straight and circular. Some difficulty is experienced in getting out the central piece of the heading; but after this is done the remainder comes down easily. The explosive employed is dynamite, which is found to answer much better than powder. The material through which the tunnel is constructed is very hard. The air-engine which drives the drill works at about 130 revolutions per minute with the air at 40 lbs. The air is compressed by a steam-engine at the top of the shaft, whilst the exhaust-air from the boring machine ventilates the tunnel perfectly.

Subaqueous Foundations.—The method of sinking cylinders for foundations by the use of compressed air was first suggested by Mr. John Wright, of Rochester, about twenty years ago, when Resident Engineer upon the Rochester bridge. Recently Mr. Wright has made certain modifications in his previous invention, in order to provide a means by which tunnels can be constructed on the beds of rivers or in other waters, to obviate the necessity of having any thickness of earth between the top of the tunnel and the bottom of the river. For this purpose, caissons or bells open at the bottom, and from which water is kept out by air under pressure, are employed, and a continuous foundation can be formed. The caisson having been lowered into position where a section of a foundation is to be constructed, the water is forced out in the usual manner, and the work of the foundation proceeded with, the section of the work being made somewhat shorter than the diameter of the caisson, in order that the latter may be lifted and moved a distance after one section of the work has been completed. Upon a continuous substructure thus formed, the tunnel is constructed in horizontal courses in a similar manner, except that instead of the sections being made solid, they are now formed of a sufficient width for the purpose, a bell of suitable size being employed. While the upper part of the first course of blocks is being built separately within the bell, a portion of the invert, or so much of the tunnel as is to be contained in the height of the lower block is formed, the hollow of the invert thus made being filled in with puddle to the full height of the block. The sides of the tunnel may also be formed in suitably shaped blocks, care being taken that the space contained within the sides is filled with clay as the work proceeds, until the tunnel is completed by arched blocks forming the roof; and when the joints are all made good, the puddle can be removed, leaving the work finished. The caisson or bell can readily be raised and shifted from place to place by a traveller, running upon rails supported on piles, the traveller being fitted with a suitable engine and travelling gear. Inside the bell a tank or hopper is fixed, and from this a shaft rises through the top of the bell to above the surface of the water, this shaft being open at each end, and dipping a short distance below the mouth of the hopper. The shaft and hopper are always kept filled with water, by means of which the escape of air from the bell will be prevented. Within this shaft is conducted a set of revolving buckets, by which all earth excavated from the bottom of the bell and thrown into the hopper can be drawn up.

Hydraulic Boring Machine.—A novel invention by Mr. Theodore Allen, of the American Society of Civil Engineers, has recently been adopted by the Department of Docks of the City of New York, with a view to obtain a survey of the hard bottom of the Hudson and East rivers, adjacent to New York City. By Mr. Allen's plan the boring rod is forced down by means of hydraulic pressure. As a basis it was considered that a pressure of 1000 lbs. to the square inch upon the area of the tube would be ample for all purposes,—that is, when a resisting of density sufficient to withstand that force was met with, it would more than suffice to sustain the weight upon the piles. The tube itself had to be of considerable area in order to bear this pressure when unsupported for some distance in the water or soft mud. A tube of $2\frac{7}{8}$ inches exterior diameter, and $1\frac{5}{8}$ inches interior diameter was deemed the smallest that could be used with safety. The length of sections of the tube was fixed at 8 feet, the weight of a section of this length being as great as could be conveniently handled. This tube was then secured or clamped to a cross head by a contrivance which, while securely holding the tube, permitted it to be turned round. At each end of the cross head a piston rod was attached, the pistons moving vertically within a cast-iron cylinder of 6 inches diameter, and having sufficient length to admit of a stroke or movement slightly greater than the length of each section of the tube. The pistons are packed with cup leather packing, and the cylinders are supplied by means of a fly-wheel pump, the proportions of which enable 50 lbs. pressure per square inch in the steam cylinder to exert a force of 500 lbs. pressure per square inch in the pump barrel. In order to regulate the pressure upon the tubes an ordinary weighted lever valve is used, the raising of the lever informing the attendant that the requisite resistance has been obtained. During the test, before the acceptance of the apparatus, the safety-valve was set at 450 lbs. to the square inch, causing a total pressure on the tube of 23,850 lbs., or 3674 lbs. to the square inch.

ENGINEERING SOCIETIES.

Institution of Civil Engineers.—Mr. Emerson Bainbridge read a paper on the 5th of March last, "On the Kind-Chaudron System of Sinking Shafts through Water-bearing Strata without the use of Pumping Machinery." The author pointed out that the plan of sinking pits hitherto practised in this country consisted in dealing with the water by means of large pumping-engines, in leaving the bottoms of the pits dry enough to allow the sinkers to block the well, and in keeping back the water in the upper strata by metal rings, cast in segments about 4 feet long, and connected by wooden joints, which were wedged tight, when all the tubbing was fixed. The evils of this system were:—1. The heavy first cost of the plant when special pumping machinery was used. 2. The expense of the wedging tubs, and the cost of fixing them. 3. The delay caused by the sinkers being compelled to work always in water. 4. The first high cost of the tubbing and of fixing it in the shaft, and the liability of the tubbing leaking in consequence of the numerous joints. In the application of the Kind-Chaudron system these evils were to a great extent avoided. This system consisted of a combination of Mr. Kind's well-known apparatus for boring wells, with an ingenious device, invented by M. Chaudron, for fixing cylindrical tubbing under water in such a manner as to make it quite secure and water-tight. A comparison between the two systems showed, that whilst with the system of sinking by the aid of pumping machinery, the average cost per foot had amounted to £114 7s., and the rate of sinking to 8·9 feet per month, with the Chaudron system the average of all the pits was equal to £22·9 per foot, and the speed of sinking to 15·8 feet per month.

On the 12th of March last Mr. J. H. Latham read a paper "On the Soonkasala Canal of the Madras Irrigation and Canal Company." This canal has recently been opened for its entire length from Soonkasala to Cuddapah, a distance of 190 miles. The objects of this canal are twofold; first, the continuous irrigation throughout the year of large areas of country in the Bellary, Koonder, and Nellore Districts; and the second purpose, apparently necessary to the success of the first, was a means of communication by canals, by which the produce of those areas could be sent to a market more cheaply than by cart or railway—more expeditiously than by cart, and more securely than by railways. After giving a brief history of the canal, the author gave detailed particulars of some of the most important works undertaken in its construction; its capabilities for irrigation and navigation; and finally concluded by a comparison between it and the Grand Junction Canal between Brentford on the Thames and Braunston.

A paper on "Explosive Agents applied to Industrial Purposes," was read by Mr. F. A. Abel, F.R.S., on the 14th of May. The nature and properties of gunpowder, and its special advantages and defects as an explosive agent for industrial purposes, was first briefly reviewed. The application of other compounds, including the use of chlorate of potash, including "poudre picrate," and those produced by the action of nitric acid upon organic substances, such as nitroglycerine and gun-cotton, were referred to, and the two latter particularly dwelt upon and explained, and their advantages for blasting purposes were enumerated. In conclusion, after referring to some recent interesting experiments of Dr. Sprengel, on the application of readily oxidisable and other powerfully oxidising liquids in the production of violently-detonating mixtures, the author showed that, even in the application of gunpowder to industrial purposes, some decided advance had lately been made, for its violent explosion could be developed, like that of all other explosive mixtures and compounds, through the agency of a detonation, whereby its action might be considerably intensified, and its application to some important classes of work, such as in submarine operations, greatly facilitated.

Institution of Mechanical Engineers.—At a meeting of this Society on the 2nd of May last at Birmingham, after the adjourned discussion upon a paper read at the last meeting, "On the Strength and Proportions of Rivetted Joints, &c.," a paper was read, "On a Steam Jet for Exhausting Air, &c., and the Results of its Application," by the President, C. W. Siemens, Esq., F.R.S., D.C.L. The form and application of the steam jet having remained hitherto essentially the same as in the original steam blast of the locomotive, it occurred to the author that much might be done to improve its effect by a judicious arrangement of the parts, so as to avoid eddies in the combined current of steam and air, and to utilise more completely the initial momentum of steam. These objects have now been effectually accomplished by the employment of a very thin annular jet of steam, in the form of a hollow cylindrical column, discharged from an annular nozzle. The air to be propelled by the steam jet is admitted through an exterior annular orifice surrounding the jet, and also through the centre of the hollow jet; and the area of the air passages is gradually contracted on approaching the jet, whereby the velocity of motion of the entering air is so much accelerated, before it is brought in contact with the steam, as to avoid the great difference in the velocity of the two currents at the point where they come together, which caused the eddies that previously impaired the efficiency of the steam jet. By the annular form of the steam jet the extent of surface contact between the steam and air is greatly increased, and the quantity of air delivered is by this means very much augmented in proportion to the quantity of steam employed. The combined jet of steam and air is discharged through an expanding delivery pipe of considerable length, in which its velocity is gradually reduced and its momentum accordingly utilised by being converted into pressure. This improved steam jet has been applied for exhausting one of the pneumatic despatch tubes employed at the Central Telegraph Station in London, for conveying the carriers containing telegraphic despatches from one station to another. Another application is to the lifting of water from a moderate depth; for exhausting the vacuum pans employed in sugar-boiling; and as a blower for accelerating the distillation of fuel in gas-producers for heating purposes.

LIGHT.

Mr. Harcourt has found that by heating to redness a mixture of hydrogen and bisulphide of carbon vapour, the latter is decomposed into sulphuretted hydrogen. The removal of bisulphide of carbon from coal-gas is thus rendered possible, for by heating the gas to redness the sulphur combines with hydrogen to form sulphuretted hydrogen, which can be easily removed by passing through a purifier containing oxide of iron. By passing coal-gas, containing 30 grains of sulphur in 100 cubic feet, through a red-hot tube, and then through an iron purifier, the sulphur was reduced to about 5 or 6 grains in 100 cubic feet. It might be imagined that the passage of the coal-gas through a red-hot tube would deteriorate its quality; but Mr. Harcourt found the contrary to be the case. By passing gas of 14·91 candles rapidly through a tube heated to dull redness, the illuminating power was found to be 15·1 candles, and by passing the gas through a tube heated to bright redness the illuminating power was increased to 16·66 candles. A parallel case to this occurs when marsh-gas is decomposed eudiometrically into hydrogen and carbon; the resultant gas occupies almost twice the original volume of the gas, but possesses a far greater illuminating power than that of the original marsh-gas, owing to the presence of acetylene or some such body. It seems easy to deduce from Mr. Harcourt's results a process for the desulphuration of coal-gas.

In reference to the very simple and ingenious arrangement for a vertical lantern made by Mr. Ferguson, and described in our last issue, we would add a further suggestion made by Prof. Morton, President of the Stevens Institute of Technology, whose form of the same apparatus we published in our last October number. This is to carry yet a step further the simplicity of the instrument by substituting a watch-glass full of water for the photographic or other objective lens. Dr. Morton also tells us that he finds this method can be developed into a very striking illustration of refraction and the action of lenses in the following manner:—A well-defined photograph on glass is placed as an object in the vertical lantern, the place of the objective being supplied by an empty watch-glass previously adjusted. There will then appear on the screen no image, but only a nebulous mass of light. On pouring water into the watch-glass, however, a sharply-defined image will come out as soon as the water ceases to move in ripples. By removing the water and substituting alcohol or some more highly refracting liquid, such as a solution of muriate of tin, a lens of shorter focus and higher magnifying power will be obtained.

Dr. Morton sends us also the following explanation of the general relation between the condenser and objective in the magic lantern, on which was founded the plan first adopted by him of separating the ordinary lantern condenser into two elements, one of which was placed before and the other after the mirror of the vertical lantern, by which the efficiency of that instrument was so largely increased. It is curious to note that this point seems to have escaped the able constructor, M. Duboscq, who publishes in *Les Mondes*, vol. xxiv., p. 649, a vertical lantern in which this very important element is absent. "If a system of condensers are well arranged, the front surface of the outside lens will be evenly illuminated, as may be seen by placing a sheet of thin paper against it, but from this surface the rays will travel outwards with all the irregularities of distribution caused by spherical and chromatic abberration, and by the action of the condensers as image-producer of the source of light." "If now the object-glass while in focus with the object, is also in focus with the front of the condenser, it will produce on the screen an image of the equally illuminated surface of the condenser, the irregularities in direction of the rays as they leave that surface having, as we know from the simple theory of image formation by lenses, no effect inimical to such a result. But if the object is moved forward on the cone of rays issuing from the condenser, then, when the object-glass is in focus with this, it will tend to produce an image of a section of the light cone made in the same plane." Here, however, the irregularities in distribution of the light before noticed have developed to the extent of rendering the area of such a cross section very irregular in illumination and colour, and this irregularly-illuminated surface the object-glass will reproduce in the image which it throws upon the screen. "If in the vertical lantern we place the condensers all together before the first mirror, then the object above the mirror will be at a considerable distance from the front of the condensers, and the ill results already named will follow. If, however, we place, first, only so much of the condenser as will bring to parallelism the rays diverging from the source of light, they will then pass on to the remaining lens after reflection, exactly as they would have done had the condenser occupied its usual position, and will evenly illuminate its surface in contact with which the 'object' finds itself, and thus they will produce a field evenly illuminated. It is this set of conditions which has defeated the attempt frequently made to use large condensers with small pictures, by moving the latter forward on the cone of rays coming from the former. For use with the vertical lantern I find the following combination of lenses makes a very good condenser:—Nearest to the light a plano-convex lens of 4½ inches diameter and focus of 9 inches; next to this, with its flat side also towards the light, a plano-convex lens of 5 inches diameter and 7 inches focus; then beyond the mirror a plano-convex lens 5 inches diameter and 8 inches focus, with its flat face upwards or away from the light. One might naturally suppose that with so rude a lens as a watch-glass full of water a very ill-defined and unsatisfactory image would be formed; but this is not the case, because the rays of light which pass through any point of the object do not spread over the whole of the object-glass (as is the case with the rays from an object which enter an ordinary portrait camera or telescope), but fall upon a small element of the lens only. They therefore acquire only the spherical and chromatic error proper to such a small element, and not that due to the entire lens. Any one familiar with the action of lenses for other purposes will be astonished by the accuracy of the image obtained in the lantern with a common plano-convex lens whose curved face is turned towards the object." "It is, of course, the previous concentration and focalising of the rays by the condenser which accomplishes this good result in the manner named."

The "Journal of the Franklin Institute" reports a lecture by Professor A. M. Mayer, at the Sheffield Scientific School, which included a very beautiful acoustic illustration of the method of determining stellar motions by the spectroscope. The lecturer dwelt upon the analogy between sound waves and those of light. Whenever one of the coloured waves composing white light is lengthened, its colour is modified in the direction of the red end of the spectrum, and *vice versa*. The motions of a star when at right angles to the view is susceptible of telescopic measurement; but, the lecturer continued, the motion of a star when in the direction of the line of sight can only be measured on the foregoing principle, the standard being the displacement from their normal position of certain lines in its spectrum. This principle is capable of illustration by means of waves of sound. With the lantern an image of a tuning-fork beating 256 times a second is thrown upon the screen. By the side of one of the prongs, and just touching it, a cork-ball is suspended by a filament of silk. On sounding a second fork tuned in accurate unison with the first, anywhere in the room, even at a distance of 30 feet, the first is thrown into vibration, and the image of the cork-ball projected a foot or two away from the prong. When, however, the second fork is carried rapidly to or from the first, no motion of the cork is perceived, the wave of sound being shortened or lengthened by an amount sufficient to throw it out of unison with those produced by the first fork. If a fork vibrating 254 times a second be now rapidly approached to the first, the waves are so much shortened as to be in unison with it and to throw the ball into motion. A fork vibrating 258 times a second carried rapidly from the first, exhibits by the lengthening of the waves the same phenomenon.

MICROSCOPY.—Dr. James Murie, F.L.S., &c., continues his paper* on the classification and arrangement of microscopic objects in a communication to the Royal Microscopical Society. The principles of classification are dwelt upon at some length, a matter of especial value in the case of large and varied collections. Several instances are given of the mode of settling the proper place of objects which might be entitled to be located in any one of several departments. For example, of egg-shell the author says, "Although composed of the salts of lime, it is virtually an animal product, and therefore to be excluded from the inorganic division. As to its physiological place, it may take rank among component elementary bodies, supposing there is such a group, and either form part of an embryological section, or come under a division accessory to the generative organs of birds. Its most natural position is illustrating the textural character and peculiarities of the enveloping masses of the young of vertebrates, and therefore subsidiary to development near the ovum." Again, "insects in amber are kept not as typical of the structure of the amber itself, but as exemplifying a peculiar nidus wherein an insect may become imbedded. I would incline, therefore, to place such an object among the groups of insects: here either close to the genus which the insect represented, or in a separate and subsidiary heading devoted to "*Insects imbedded in foreign substances*" at the end of *Insect structure.*

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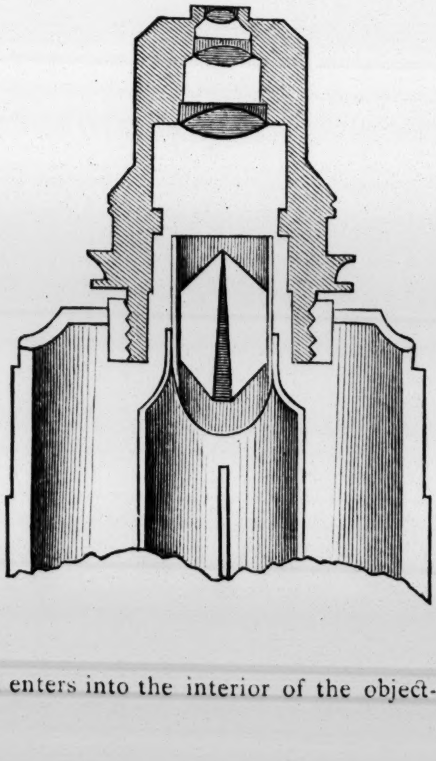
* Monthly Micro. Journ., vol. i., p. 69; vol. vii., p. 201.

"Ought pearls to go along with *shells*, or as *examples of disease?* This again depends somewhat upon the nature of the collection. Strictly speaking, pearls are but a morbid condition of the nacreous material of shells, and hence are true examples of disease. They therefore, according to principle, should be ranged among *Pathological textures*. In a miscellaneous series, however, where pathology forms either an unimportant factor, or is not meant to be exemplified at all, then pearls necessarily come under the heading *Mollusca*, or *shell;* and a sub-series either together or after the representative genus to which the shell belongs.

Respecting cabinets, after discussing the merits of the various contrivances for storing objects, Dr. Murie advocates for large and increasing collections a system of small cabinets of similar dimensions, each devoted to a group or subsidiary division, and numbered and labelled accordingly, and so arranged that to all intents and purposes they represent but one vast cabinet. In support of this opinion, Dr. Murie calls attention to the great convenience of such a system as exemplified in the Botanical Department and Insect Room of the British Museum. He says, "such is my *beau ideal* of a microscopic cabinet, compound yet harmoniously single; adapted to meet the wants of a limited, a moderate, or a numerous series; expansion being in the ratio of increment of slides. But, furthermore, the same principle is applicable to very modest microscopical collection; such, indeed, as even the amateur, or those of limited means may aspire to. As a closing sentence to this clause, I may even make bold to say that, like other fashions and hobbies, that of cabinets is an infectious one; a piece of handsome furniture is attractive. Would that the zest for a thorough mastery of the contents was as powerful a stimulant. The whole paper, as well as the preceding one, is worthy the attention of those interested in the arrangement of microscopic or other natural history collections.

FIG. 1.



Mr. J.W. Stephenson, F.R.A.S., brings before the Royal Microscopical Society an improvement on his erecting binocular. The prisms are very much reduced in size, and are placed in a small brass tube, which is attached to the nozzle of the microscope in such a manner that it projects and enters into the interior of the object-glass mounting, and is thus brought very close to the back combination of the objective; this change of position, and also the reduction of the amount of glass traversed by the divided pencils, materially improves the definition of the instrument, which can now be used satisfactorily with a power of ⅛th of an inch. The dimensions of the prisms are 0·68 of an inch in length, 0·412 of an inch in width, and 0·2 of an inch in thickness, and are inclined to each other at an angle of 4¾°; this makes the angle between the bodies 9½°, and the imaginary point to which they converge nearly 15 inches. Provision is made for the employment of polarised light by substituting for the upper prism a plate of black glass so placed that the light is reflected from its surface at the polarising angle of 56¾°; a suitable alteration in the inclination of the bodies is made with this view without in any way affecting the use of the microscope for ordinary observations. This arrangement is found to give much better definition than a Nicol prism placed within the body.

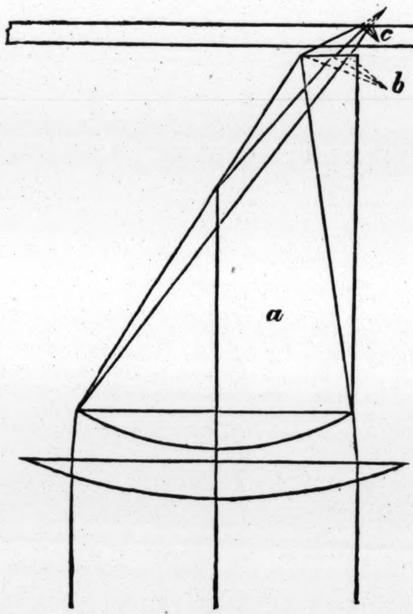
Captain Hutton gives, in the "Monthly Microscopical Journal" for May, an account of his examination of three kinds of vegetable fibres: those of *Phormium tenax*, "New Zealand Flax," and "Sizal" and "Manilla Hemp." He remarks, as most persons do who have studied the subject of vegetable fibres, that there is no difficulty in distinguishing these substances when in quantity; but that character is lost when only a small amount is available for examination. The following results of microscopical observations are given:—*Manilla*. Fibrous bundles oval, nearly opaque, and surrounded by a considerable quantity of dried up cellular tissue, composed of rectangular cells. The bundles are smooth; very few partly-detached ultimate fibres are seen, and no spiral tissue. *Sizal*. Fibrous bundles oval and surrounded by cellular tissue. Smooth and very few ultimate fibres projecting from the bundles. More translucent than Manilla, and can always be recognised by the large quantity of spiral fibres mixed up in the bundles. *New Zealand Flax* (*Phormium tenax*). In machine-dressed *Phormium* the bundles are translucent and irregularly covered with tissue. Spiral fibres can be detected among the bundles, but not in the same quantity that is seen in Sizal. Many more ultimate fibres stick out from the bundles, which are flat instead of oval. In those places where the bundles are entirely freed from tissue they are generally divided longitudinally into two or more smaller bundles or fasciculi, and in these places the number of half-detached ultimate fibres is greatly increased; these are, however, rarely broken, most of them having the end perfect. Spiral fibres are here absent. In Maori-prepared *Phormium* the bundles are almost entirely free from tissue, and quite so from spiral fibres. They are always broken up into many fasciculi, which average, perhaps, some twelve or fifteen ultimate fibres in each fasciculus. Many ultimate fibres are semi-detached, and they are much more broken than in machine-prepared fibre. For examination of the ultimate fibre Captain Hutton recommends boiling for two or three hours in a weak solution of potash, and separation of the fibres by dissection under the microscope in water. The ultimate fibres of Sizal will be found to separate easily, those of *Phormium* with more difficulty, while it will require great care to prevent breaking those of Manilla; this latter fibre will require a much longer boiling to render separation easy. According to Captain Hutton's table of measurements, the average length of the fibre of *Phormium* will be found to be nearly twice that of the others; while the average diameter is not more than half that of Manilla, which is again much less than that of Sizal. The cell wall of *Phormium* is also much thinner than that of either of the other two. These researches are a valuable contribution to a subject the histology of which is at present very little known. Good and characteristic distinctions among vegetable fibres are much to be desired, and the present paper is a step towards grappling with the great difficulties into which these researches are attended.

Dr. John Matthews about two years back produced a simple and ingenious self-centreing turn-table; this proved very useful in varnishing slides, which were originally truly centred; its convenience for this purpose, however, rendered it quite useless in the case of slides which were, as in the majority of instances, eccentric. This defect has been remedied by adding a second plate capable of allowing the slide to be thrown out of the centre to the extent required. This new turn-table combines all the advantages of the old construction with those peculiar to its original self-centreing form, and is also provided with a convenient hand-rest, which will be found a great assistance in forming cells with varnish, as it enables the brush to be held with very great steadiness.

Mr. F. H. Wenham has produced a $\frac{1}{5}$th objective capable of working, both as a dry and immersion lens, with the same front. Its performance under both conditions leaves nothing to be desired.

An account of "An Improved Reflex Illuminator for the Highest Powers of the Microscope" is communicated to the Royal Microscopical Society by Mr. F. H. Wenham.* It consists of a cylinder of glass (*a*) ½ an inch long and $\frac{4}{10}$ths of an inch diameter, the lower surface of which is worked convex to a radius of $\frac{4}{10}$ths of an inch. Starting from the bottom edge, the cylinder is worked off to a polished face at an angle of 64°: close beneath the cylinder is set a plano-convex lens of 1¼ focus. Parallel rays sent through the lens, after leaving the lower convex surface of the cylinder, would be refracted to the point shown by the dotted lines if continued in solid glass, but by impinging on the inclined polished surface (which is far within the angle of total reflection) they are thrown on the flat segmental top; here they would be totally reflected and beaten down again to the point (*b*) outside the cylinder; but if an object slide (*c*) be laid over the flat top with an intervening film of water, the rays proceed on till the focal point reaches the upper surface, or is slightly beyond it; here total reflection now takes place; all the light is concentrated to a minute spot in the centre of the field of view of the microscope, and most of the rays are available for any object brought there by traversing the slides over the water top of the illuminator, which must be kept full without allowing any to run down the reflecting surface. This illuminator is fitted into the ordinary sub-stage, and has an independent rotatory movement of its own like that of Nachet's prism. The cylinder is to be brought up nearly level with the stage. The centre of rotation is set true by a dot on the fitting seen with a 1½ objective. A drop of water is then placed on the top, upon which the slide is laid. The required objects on the slide are found with a low power, and may be distinguished by their brilliant appearance, while those on the cover are nearly invisible. The light is thrown up either by the plane or concave mirror. The former is generally the best and most controllable; the lamp should not be placed much beyond the stage, else its direct rays will get underneath and mar the blackness of the field. Having got the best effect by tilting the mirror, the illuminator is to be rotated, by which means various effects are brought out. The paper reviews the author's past contrivances for the same purpose, and anticipates the objections that may be raised against

FIG. 2.



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* Monthly Micro. Journ., vol. vii., p. 237.

the new arrangement. It also contains some valuable remarks on total reflection and the transmitting power of various media, which are too long for quotation, and cannot be profitably given in abstract.

HEAT.

M. F. Tommasi has endeavoured to show the possibility of converting into dynamic work the expansion produced in liquids by heat; and the easy application of this motive force to the hydraulic press. He endeavours to show that by the expansion of oil instead of water, the pressure being caused to act directly upon the piston of the press, five-tenths of the quantity of heat employed in the ordinary steam engine produces the same degree of tension. The apparatus is very simple, consisting merely of a boiler in communication with a piston-box, the boiler being filled with colza or other oil, and heated by means of gas. It would appear that there is effected over other machines a saving of about 75 per cent.

The "Berichte der Deutschen Chemischen Gesellschaft zu Berlin," has an important paper on the specific heat of carbon. Dulong and Petit showed by experiments with twelve of the metals, that the product of the atomic weight and specific heat—in other words, the so-called atomic heat—had the same value, about 6·5, for all elements. Experimentalists have, from time to time, observed many striking departures from that law, and a comparison made by the author of the paper, H. F. Weber, of the numbers obtained by Regnault, De la Rive, Kopp, and Wüllner, as representing the specific heat of carbon, clearly shows that the different allotropic modifications of this element have very different specific heats, no one of which obeys Dulong and Petit's law; while the values assigned by these physicists to the specific heat of any one modification vary within wide limits. This is probably due to the fact that the specific heat of carbon in all its allotropic conditions varies with the temperature. Experiments with two large diamonds, conducted in the physical laboratory of Professor Helmholtz, in Berlin, have shown that the specific heat of carbon increases with the temperature to a degree surpassing any other substance, the specific heat of diamond being trebled by an increase of temperature from 0° to 200° C.

The following experiment has the advantages of certainty in its performance and of novelty. Take a wide glass tube open at both ends, and some little distance into the interior push a piece of fine wire gauze. If the gauze is now heated to redness over an ordinary Bunsen burner and then removed, it will shortly emit a shrill note for five to ten seconds.

The Real Evaporative Efficiency of Steam-Boilers Determined.—The American Institute of the State of New York have made public the result of an important series of trials of steam-boilers which was made at their last annual exhibition. The committee appointed to decide upon the merits of all steam apparatus and machinery entered at the "Fair," consisted of R. H. Thurston, Professor of Mechanical Engineering at the Stevens Institute of Technology, Chairman; and T. J. Sloan and Robert Weir, well-known engineers, Members. To secure an accurate determination of the amount of water passing out of the boilers, both evaporated and unevaporated, it was led into a large surface condenser. The weight of the water of condensation and of the condensing water was exactly measured, and the temperature of the water of condensation and the condensing water, of the steam in the boiler and of the entering feed and injection water, was obtained by delicate thermometers. The greatest care was taken to insure such accurate determination as should make the results of these trials valuable as *standards* with which to compare those of future similar trials. The log was kept by students selected from advanced classes of the Stevens Institute of Technology, and under the supervision of the chairman, himself a professional and experienced engineer. The committee thus obtained results that are extremely valuable to the engineer, as exhibiting the true efficiency of what they considered good boilers of quite dissimilar forms, and hardly less useful to the physicist, as giving the modulus of efficiency of large evaporating apparatus. The arrangement described enabled a determination of the quantity of heat transferred to the condenser from each boiler, during its twelve hour's trial, to be readily made. The weights of coal and wood were also recorded as is usual. To ascertain the weight of water actually evaporated and that carried over unevaporated, the committee use the formula, $Hx+h(W-x)=U$, where H is the number of thermal units transferred by each pound of steam, h the thermal units carried over to the water of condensation by a pound of water, x the weight of steam, and $W-x$ the weight of water, by which the total quantity of heat U is transferred from boiler to condenser. Introducing other values from the log, and solving for x, the results exhibited in the fifth column of our table are easily deduced. At the end of the elaborate report of the committee is a very complete table of results, from which we extract the following:—

Name.	Style.	Area of Heat Surface.	Square feet required to evaporate one cubic foot per hour.	Ratio H. S. to grate area.	Percentage of water primed.	Temperature of flues.	Evaporation per lb. combustible feed 212° F.	Modulus of Efficiency.
Root ..	"Sectional*"	876½	23·59	32·5	0·00	416·6° F.	10·64	0·709
Allen ..	"Sectional*"	920	17·41	28·5	0·00	345·8° F.	10·60	0·707
Phleger ..	"Sectional*"	600	22·74	26·1	3·26	503·7° F.	10·49	0·699
Lowe ..	"Tubular†"	913	21·63	24·2	6·90	389·6° F.	10·40	0·693
Blanchard	"Tubular‡"	440	33·48	51·8	3·00	221·6° F.	11·34	0·756

ELECTRICITY.

M. Bouman, of Holland, has effected a considerable improvement in the arrangement of the Léclanché cell, rendering the pile still more constant. In the flat-bottomed glass jar a plate of gas carbon and a rod of amalgamated zinc are placed vertically, a short distance apart. The intervening space and the surrounding parts of the vessel are then two-thirds filled with the usual mixture of coarsely-pulverised coke and black oxide of manganese. In order to prevent the zinc poles from coming into contact with the black mass, it is protected by a cover of woollen cloth. The porous cup is thus dispensed with. Léclanché made the connection with the carbon plate by means of a covering of sheet lead; but as this was liable to oxidation, complete contact was often destroyed. Bouman remedies this evil by cutting a slit in the gas carbon pole, and inserting a platinum wire, on the ends of which are clamps in connection with the outer circuit. Thus modified, the elements were found to run without interruption for a year sufficiently strong to drive an electric clock, and to sustain an alarm clock for two years. Mr. Higgs, by arranging a series of small-sized carbons and cylinders of zinc in alternate series in a similar manner to the series of the old iron-zinc deflagrator, has been enabled to dispense with additional cells, at the same time evolving the full electro-motive force. He has succeeded in introducing into one small vessel twelve couples of zinc and carbon (adopting M. Bouman's method of surrounding the zinc with felt), thus deriving the electro-motive force of about ten Daniell's cells from a very diminutive battery. Batteries exposing a larger surface are being made on the same principle.

An improved method of nickel plating has been devised by Mr. Keith, by which he obtains a flexible and tenacious deposit. The deposits at present obtained are so brittle that the articles will not suffer the least bending. The invention consists in adding to the various solutions of nickel, whether formed of single or double salts, materials which by their presence prevent the decomposition of the solution of the plating bath, and the deposition of oxide of nickel and other impurities upon the articles receiving the coating of nickel. There is added to the solution of nickel one or more salts, either single or double, acid or neutral, or associate, formed by the union of organic acids, acetic, citric, and tartaric, with the alkalies and alkaline earths, ammonia, soda, potash, magnesia, or alumina. These additions will, it is asserted, counteract the tendency to decomposition of the solution by action of the electric current. These various organic acid salts may be added interchangeably and collectively, though the inventor prefers to use, in case of the double salts of nickel and alkalies and alkaline earths, the organic acid salts which have for their bases the alkali or alkaline earth which is associated with the nickel in its double salt. Thus, when using a solution of nickel and ammonia, an organic acid salt of ammonia is preferred, though the similar salts of soda and potash will answer very well. In case of using a solution of a double salt of nickel and potash, or a double salt of nickel and soda, an organic acid salt of soda and potash is selected. Of the salts which can be used to accomplish the effect, the tartrates are preferable. A comparatively small quantity of the organic salts is necessary to be added, though more will not change the character of the deposit. The following bath is said to work well:—To 20 gallons of a solution in water of the double sulphate of nickel and ammonia of 7° Baumé, add 1 gallon of a solution, of an equal gravity, of neutral tartrate of ammonia in water. Mix well, and the bath will be ready after standing a few hours.

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* Wrought-iron tubes. † With special provision for perfect combustion.
‡ Feed-water heater and mechanical draught.

Two new electric detonators for mining purposes have been introduced at the Royal Arsenal, Woolwich, one for land, the other for marine service. The first consists of a tin tube filled with fulminating mercury, surmounted by a spherical head of beech-wood. Through this head, and embedded in gutta-percha to insulate them, run the electric wires, separated at their extremities. In this separation, and between the fulminating mercury and the wires, a small quantity of loose gun-cotton is placed. The passage of an electric current generates sufficient heat to ignite the gun-cotton. The second detonator is a modification of the old platinum wire fuse, and consists, like the other, of a tin tube filled with fulminating mercury and with a beech-wood head. To the ends of the insulated wires is attached about $\frac{3}{10}$ths of an inch of platinum wire 0·003 inch thick. Some loose gun-cotton is placed around the wire, and is ignited when the wire is raised to incandescence by the passage of the current. The ignition of the gun-cotton explodes the fulminating mercury, which in its turn explodes the powder.

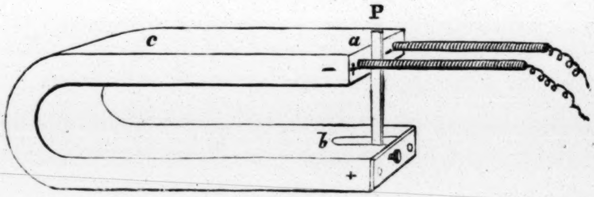
M. Ruhmkorff has invented a new or rather modified apparatus for the generation of ozone. The modes of preparation of this body have been:—1. By the decomposition of water by the pile; 2. By means of phosphorus; 3. By the action of concentrated sulphuric acid upon barytic oxide; 4. Finally, by passing a series of sparks from an electrical machine or from an induction coil through oxygen gas. The apparatus of M. Ruhmkorff is founded on this last method. It consists of a rectangular wooden case containing several horizontal ranges of metal plates, the alternate plates being connected, the one set to one terminal and the other set to another terminal, in connection with the poles of the battery or machine. These plates being thus arranged as a condenser serve to increase the intensity and number of the sparks. Tubulures connected with a reservoir of oxygen keep the case supplied, the ozone being drawn off by an aspirator. With this apparatus many new results have been obtained shortly to be brought to the notice of the scientific world.

The metal cadmium has been found by Dr. Schonn capable of being rendered, under certain circumstances, indifferent to the action of acids. It has long been known that iron, if plunged into nitric acid of a certain degree of concentration, acquires a peculiar surface condition, rendering it indifferent to the action of the strongest acid. Iron which has undergone this surface change has been termed passive. It appears, too, that such iron has acquired some peculiar physical qualities, since it will form a galvanic circuit with ordinary iron; the changed metal behaving electrically negative to the other.

That such iron has really been decidedly altered in character is evinced again by the fact that it refuses to reduce copper from solutions of its salts. It appears from Dr. Schonn's observation, that if cadmium is wrapped with some platinum wire, it may be placed, without being in the least acted upon, in strong nitric acid, though if the wire surrounding is removed, or if the acid is diluted, the cadmium is instantly attacked, thus showing that the passivity of the cadmium is due entirely to its contact with the platinum. The same author has shown that tin will give a similar phenomenon.

M. D'Arlincourt has invented a relay said to be very easily adjusted and effective in its working. At the negative extremity, *a*, of a powerful horse-shoe magnet, *c*, are fixed the two poles of an electro-magnet. A vertical bar of iron, P, centred at *b* in the positive pole of the horse-shoe permanent magnet, and therefore permanently positively magnetised, vibrates between the two poles of the electro-magnet on the other extremity of the horse-shoe magnet. When a series of currents are passed through the wires of the electro-magnet, the bar P necessarily executes a corresponding series of vibratory movements, being displaced from the positive pole of the electro-magnet, to which it returns on an interruption or change in the direction of the current. In this relay it is said that the difficulty of residual magnetism arising from the coercive force of the iron of the electro-magnet, is removed, and that the degree of rapidity of the oscillations of the bar consequently depends upon the rate at which the current can be made and interrupted in the line. With the relay disposed as a translating apparatus at Paris, messages were transmitted from Marseilles to London, traversing the cable at Dieppe. The trial showed the relay capable of being worked at a high speed and with great precision.

FIG. 3.



M. Lenz has lately submitted a valuable paper on the properties of iron deposited by the electric current. He arrives at the following conclusions:— That iron and copper deposited by the galvanic current retain a gas, principally hydrogen. The volume of the gas absorbed by the iron varies between very wide limits, being sometimes as much as 185 times its own volume. The absorption of the gas takes place principally in the first layers of metal deposited. The absorbed gas may be disengaged by heating the iron to a temperature of 100° C. These researches are likely to throw great light upon the electrolytic deposition of metals, and the obtaining of a reguline deposit.

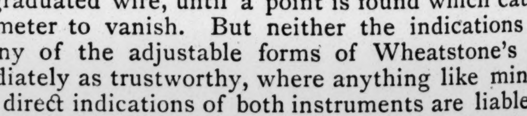
M. Volpicelli finds that the least flexure produced in a strip of metal gives rise to an electric current when the strip forms part of a conductive circuit. This was shown for the first time by Peltier, and the results of his experiments were confirmed by M. A. de la Rive. Peltier formed a large circle with a copper wire, which he put in communication with a galvanometer of small resistance, and found that by bending the copper wire he produced a current in the galvanometer that could not be attributed to the magnetic influence of the earth. M. Volpicelli has repeated these experiments with a reflecting galvanometer, and has arrived at numerous new results. He finds that the electric current due to flexure may be obtained not only with iron, but with all metals; but that copper, under the same circumstances, produces on an astatic needle a greater deflexion than any other metal. These currents present the remarkable fact of an entire transformation of force into electricity. The currents do not sensibly depend upon the heat produced by flexure. Flexures in contrary directions in the length of the wire produce currents in opposite directions. A diminution or augmentation in the rapidity of flexure produces a diminution or augmentation of the intensity of the electric current. A strip of different metals soldered together gives a current of less intensity than a strip of a single metal.

It is interesting and not uninstructive to occasionally take retrospective views of progress in science, and to note the previsions of the more striking inventions. Whether Shakespeare when he made Puck say, "I'll draw a girdle round the earth in forty minutes," had dreams of the then future electric telegraph, cannot be supposed; but we have more definite foreshadowings in Strada's "Prolusiones Academicæ," 1617, proposing a dial with alphabet and magnetic needle. Addison alludes to this invention in the "Spectator," No. 244, 1712. Glanvill, in his "Vanity of Dogmatising," 1662, says:—"To confer at the distance of the Indies by sympathetic conveyance may be as useful to future times as to us in a literary correspondence." Evidently he is here thinking of the magnetic needle, for he continues afterwards to discourse of "conference at a distance by impregnated needles." Bailey's "Dictionary," 1730, article "Loadstone," says:—"Some authors write that, by the help of the magnet or loadstone, persons may communicate their minds to a friend at a great distance; as suppose one to be at London and the other at Paris, if each of them have a circular alphabet, like the dial-plate of a clock, and a needle touched with one magnet, then at the same time that the needle at London was moved, that at Paris would move in like manner, provided each party had secret notes for dividing words, and the observation was made at a set hour, either of the day or of the night." Sir Francis Ronalds, in 1816, constructed a tension telegraph at Hammersmith, the signals being read off pith balls. In 1816 also Andrew Crosse said:—"I prophesy that by means of the electric agency we shall be enabled to communicate our thoughts instantaneously with the uttermost parts of the earth." This remark, then a wild chimera, has been quickly achieved; not only can we communicate with the most remote continent, but we could, undoubtedly, had we the wires laid, telegraph a signal eight times round the world in one second.

In Pflüger's "Archive," Professor L. Hermann has described some experiments as to the conductibility of living muscle. He finds that living muscle offers very much greater assistance to an electric current passing across the fibres than along them, in the ratio of 7 : 1. Muscles in the condition of *rigor mortis* do not show this difference. The specific resistance of living muscle in the longitudinal direction, taking the length of mercury as unity, is 2,330,000, and in transverse direction 15,134,000. A similar difference occurs in the case of the nerves, the ratio being then 5 : 1. The specific resistance of nerve in the longitudinal direction is 2,554,000, and in the transverse direction 12,586,000, the resistance of mercury being again taken equal to 1. The longitudinal resistance of nerve is augmented by heating it to 50° C. (122° F.), the transverse resistance simultaneously diminishing. Professor Hermann thinks these differences of the resistance of the longitudinal and transverse sections of muscle and nerve due to the different polarisation of the sheath and nucleus of the fibres, and elucidates this by mathematical formulæ.

Professor J. T. Bottomley, M.A., F.C.S., describes the improved form of gravity battery, as devised by Sir William Thomson, and in use in the Physical Science Laboratory of Glasgow University, as follows:—The cell is of glass, a pan made by glass-blowers for containing milk. The diameter is 21 inches. A disc of thin sheet copper is laid on the bottom; and a thick copper wire covered with gutta-percha is soldered to the copper disc, and rises to the top of the cell as an electrode. In the upper part of the cell is a heavy mass of zinc, cast into the form of a circular gridiron, with three ears or projections, which rest on the edges of the glass. The gridiron shape is adopted in order to permit the hydrogen to escape. The distance between the zinc and copper plates is about 2½ inches. A large sheet of parchment paper covers the under surface of the zinc, and the corners and edges of the paper are brought up round the vertical sides of the zinc, so as to form a kind of bag round it. The parchment paper is thus a separator between the mass of liquid in the cell and that immediately surrounding the zinc. There is a circular hole in the middle of the zinc, and the tube of a glass or earthenware funnel passes through this and through a hole in the parchment paper, the edges of which are tied round the tube, down to the bottom of the cell. The cell is then filled up with a saturated solution of sulphate of zinc till the level of the liquid is higher than that of the top of the zinc; and on the top of this a layer of pure water 2 or 3 inches deep is poured carefully, so as to avoid mixing. The pure water forms an atmosphere into which the sulphate of zinc formed during the action of the battery may diffuse, and thus crystallisation is avoided. To set the cell in action crystals of sulphate of copper are put into the funnel. The dense solution flows down over the copper plate at the bottom, and in less than five minutes the cell is in full work. The average resistance of each cell is 0·19 of a B.H. unit.

Professor G. Carey Foster, F.R.S., has recently brought forward some valuable observations and improvements on the Wheatstone bridge. The fault of this instrument in its usual form is, that the resistance of the copper bands at the two angles is not taken into account. When large resistances have to be measured the importance of this omission is very small; but when resistances are to be measured smaller than the resistance of the apparatus, it is at once apparent that the mistakes incurred become serious. The essence of the fault lies in this, that the same amount will be added for resistance of the band whether the measurement be one or a thousand; and to make it quite flagrant, the nature of the fault is of the kind that would make $(1+a)$ a thousand times less than $(1000+a)$. Suppose a to be 1 only; then 2 would be made to answer for the thousandth part of 1001. For the purpose of making accurate measurements of very small resistances, such as those of short lengths of wires, it is essential that we should either have a standard of comparison, the value of which can be changed continuously, or, in other words, by indefinitely small amounts; or, that the method adopted for comparing the unknown resistance to be measured with an invariable standard, should be such as to enable us to vary continually, or by indefinitely small amounts, the indicated ratio between the unknown resistance and the standard. The former of these alternative means of measurement, namely a continuously adjustable standard, is afforded by the rheostat of Wheatstone and Jacobi; and the second, or a continuously adjustable method of comparison, is afforded by those forms of Wheatstone's "Differential Resistance Measurer" in which the ratio between the resistances to be compared is established by moving one of the galvanometer contacts backwards and forwards along a graduated wire, until a point is found which causes the current in the galvanometer to vanish. But neither the indications of the rheostat nor those of any of the adjustable forms of Wheatstone's bridge can be accepted immediately as trustworthy, where anything like minute accuracy is required. The direct indications of both instruments are liable to require corrections, the most important of which are those required on account of the resistance of connections not represented in the resistance of the scale, and those required on account of irregularities in the diameter or conducting power of the wire by which the adjustments are made. Professor Foster proposes to employ a graduated wire as an adjustable standard for the measurement of any resistance less than its own, in such a way as to eliminate entirely from the result the resistance of the connections by which it is united with the rest of the circuit. A German silver wire, E F, one metre in length,



graduated in 1000 millimetres, is connected at the ends with a copper band, which passes at right angles to each end of the wire, and runs parallel to it on the opposite side, where it is interrupted at A, B, C, and D, for the introduction of conductors of known and unknown resistances. In the ordinary use of the apparatus, the gaps A and D are closed, either with thick copper latches of insensible resistance, or by wires, the resistances of which are known in comparison with that of the standard wire, EF. The resistances to be compared are inserted at B and C. The battery wires are connected with binding screws at *g* and *h*, one terminal of the galvanometer being connected to the screw, *k*, the other galvanometer contact being in connection with a sliding contact, which is moved backwards and forwards on EF, until the position is found which causes no current to pass through the galvanometer. It is then clear that the scale reading corresponding to this position would in general indicate the true ratio of the resistances at B and C, only when the resistance of the copper band is an insensible fraction of these resistances as well as of the resistance of the wire, EF. But if the resistance to be measured is less than that of the whole metre wire, a measurement of it in terms of the latter, which is quite unaffected by the resistance of the connections, can be made by obtaining the balance by the sliding contact on EF; first, when the unknown resistance is inserted at D, and a connector of insensible resistance at A; and secondly, when the two have been interchanged, the gaps B and C being occupied by any convenient conductors which do not differ more in relative resistance than the wire to be measured, and the whole of the wire, EF. By inserting two resistances at A and D, and getting the balance upon EF, and then interchanging them, and getting the balance again, the difference of their resistances is obtained in terms of the resistance of the standard wire. For resistances inserted at A and D are equivalent to ungraduated prolongations of EF, and, therefore, when the balance has been obtained by adjusting the sliding contact, in order to maintain it after interchanging the conductor at A and D, the contact must be shifted a length of EF, the resistance of which is equal to the difference of the resistances at the two ends. When the resistance of one of the conductors A or D is negligible, that of the other is given by the shift of the sliding contact required to maintain the balance when this conductor is inserted; first at one of the end gaps and then at the other. Thus the wire, EF, becomes an adjustable standard of resistance, the indications of which are unaffected by the resistance of the end connections.

M. Böttger states that copper and brass may be coated with metallic zinc in the following way:—Finely divided zinc, in a non-metallic vessel, is covered with a concentrated solution of sal-ammoniac; this is heated to boiling, and the articles of copper or brass, properly cleansed, are introduced. A few minutes then suffice to produce a firm and brilliant coating. The requisite fineness of the zinc is produced by pouring the molten metal into a mortar, and triturating it until it solidifies.

Not an unimportant feature in electrical science is its application to military telegraphy. At a recent meeting of the Society of Telegraph Engineers, Capt. E. D. Malcolm, R.E., read an interesting paper, detailing the progress made in our military field telegraphs, as calculated to supply the communicating link between the outposts and the army. It appears that we have at present one troop of the Royal Engineer train devoted to this service, this troop being divided into three sections, each carrying twelve miles of wire in half-mile lengths. These pieces can be conveniently joined together by means of an ebonite jointer, which makes a practically water-tight joint in less than half a minute, and which, in the case of searching for faults, can be divided in a shorter time. The cable is a strand of seven No. 22 B.W.G. copper wires, insulated by Hooper's compound. It is 3 in. thick and weighs 300 lbs. per mile. It is rolled on wooden drums, placed on waggons drawn by six horses. The poles are of wrought-iron tubing in two lengths, the butt 10 feet long and 1¼ inches in diameter, the top 9 feet long and 1 inch in diameter, fitted inside the lower half and fixed by a bayonet catch. The wire is carried and insulated in a wooden plug fitting into the top of the pole. The earth plates are of wrought-iron, 18 inches long, 4½ inches wide, and ½ inch thick, and strong enough to be driven home in any soil; while they are accompanied by a six-gallon cask of water to insure moist earth. The office-van contains a pair of Morse recording instruments, fitted with Siemens's polarised relay, and with Digny's ink-roller. The battery is a form of Daniell's, arranged by Sergeant Mathison, R.E.

TECHNOLOGY.

According to Dr. J. M. Maisch, an excellent liquid glue about the consistency of molasses is made by dissolving glue in nitric ether; this fluid will only dissolve a certain amount of glue, consequently the solution cannot be made too thick. It is much more tenacious than that made with hot water. By adding a few pieces of caoutchouc, cut into scraps the size of buckshot, and allowing the solution to stand a few days, frequently stirring, it will resist dampness twice as well as glue made with water.

In a long interesting paper on the alloys now frequently employed for making imitation jewellery, known as Abyssinian gold, Talmi gold, &c., Dr. C. Winkler points out that the alloy is not galvanically gilt, but is plated; that is to say, a very thin sheet of gold is made to adhere to a yellow metal by rolling them together, and afterwards shaping, moulding, and chiselling by means of steel tools, the amount of gold varying from 1·03 to 0·03 per cent. As regards wear and tear, the author admits that, by careful plating, these articles really answer well.

The use of inks of a similar composition to that now generally employed appears to be of more ancient date than is generally supposed, for on examining a manuscript of the year 910, and belonging to the papers of the Cluny Abbey (Paris), Dr. Balard found that the ink it was written with was similar in composition to that now in use: it appears that MM. Coupier and Collin have succeeded in preparing an ink which is not acted upon by nitric and hydrochloric acids, chlorine, or bromine; it is not, however, quite proof against alkalies.

The very common use, especially in England, of soda for washing linen is very injurious to the tissues, and, moreover, has eventually the effect of yellowing it. Dr. Quesneville states that in Germany and Belgium the following mixture is now extensively used:—2 lbs. of soap are dissolved in 25 litres of water as hot as the hand can bear it; three large-sized tablespoonfuls of liquid ammonia and one spoonful of best oil of turpentine are then added. These fluids are incorporated rapidly by means of beating the soap-suds and other fluids with a small birch-broom. The linen, &c., is then put into the liquid and soaked for three hours, care being taken to cover the washing-tub with a closely-fitting wooden lid; by this means the linen is readily cleansed, requires very little rubbing, and there is also a saving of time and fuel. Ammonia affects neither linen nor woollen goods, and is largely used as washing-liquor in the North of England.

The following method is recommended by M. Mène for dyeing veneer wood. The wood is first steeped for twenty-four hours in a solution of caustic soda, and boiled with it for half an hour. It is then washed, to remove all the alkali, and having become as soft as leather and equally elastic, as well as capable of absorbing dye-stuffs, it is immersed for twenty-four hours, first in a decoction of logwood, and then, after having been superficially dried, into a boiling solution of sulphate of iron. When required to be yellow-dyed, it is immersed in a solution of picric acid to which ammonia is added. Wood, after steeping in soda, may also be dyed with coralline. The dyes are fast, stand varnishing, and thoroughly penetrate through the whole of the wood, which, after drying, may be sawn and veneered.

C. Daniel has described a method of painting with oil paints upon tin-foil stretched uniformly on sheets of plate glass until the painting and varnishing are finished. The tin-foil thus prepared is used instead of paper-hangings, and for decorative purposes; gilding can also be applied.

A rapid dryer for oil-paints and varnishes is formed by dissolving in 100 parts of water by the aid of heat, 12 parts of best shellac and 4 parts of borax; pouring the solution, after cooling, into bottles, which should be well corked. According to M. Mène, this solution is mixed with oil of turpentine, and added to oil-paints; the liquid may also be employed as a varnish.

A very good wood varnish for furniture and other wooden objects is made by adding to 1 kilo. of fluid copal varnish 15·62 grms. of best boiled linseed oil, and heating the mixture. The wood to be varnished is first coated with a solution of gelatine, to which either some precipitated chalk or some red ochre is added, according to the nature of the wood. When the coat of varnish is dry the article is rubbed with a solution of wax in ether.

It is well known that it requires some tact to bend a glass tube with an even curb and without collapsing its sides, and many chemists never do succeed in bending them skilfully. Prof. J. Lawrence Smith bends them satisfactorily by using the flame given by the Bunsen burner described in his article on alkali determination in silicates in vol. xxiii. of the "Chemical News." The extremity of the burner is flattened out so as to give a short and thin but broad flame, something like the flame of an ordinary gas-burner. The tube is placed in this flame and turned round and round, until a good heat is given to the tube; it is then withdrawn from the flame and can be bent with a perfect curve and without collapse of the sides of the tube. A tube of 1 centimetre and more can be thus bent very readily.

Sulphur is recommended by M. J. Ménard as a lubricating material. To 100 kilos. of good colza oil add 5 kilos. of sulphur, and heat this mixture to from 130° to 140° until all the sulphur is dissolved. It is said that, being a bad conductor of heat, sulphur prevents the heat caused by the friction of machinery being carried over upon the oil, which can therefore serve for a longer period than usual as a lubricating medium.

Glycerine has been found by experience to be useful as a means of increasing the elasticity and strength of leather. C. Mène states that hides which have been partly tanned by the usual process, may be greatly improved—especially if required for machine-belts—by being soaked for some time in glycerine.

CHEMICAL SCIENCE.

It will be remembered that in 1869 a Lectureship was founded by the Chemical Society in honour of the illustrious Faraday, to be held by some eminent foreign *savant*, who during the term of his tenure, was to deliver a discourse before the Society. The second "Faraday Lecture" was delivered on May 30th by Professor Cannizzaro, of Palermo, at the Lecture Theatre of the Royal Institution. The learned Professor's discourse was entitled "Considérations sur quelques Points de l'Enseignement Théorique de la Chemie." On Friday a dinner was given to the Professor, at which about 150 were present, including the Italian Ambassador and the Right Hon. the Chancellor of the Exchequer.

At the meeting of the chemical section of the German Association for the Advancement of Science, at Rostock, Professor Schulze read a paper on the direct oxidation of carbon by means of permanganate of potash in an alkaline solution, which excited lively debate, and was justly regarded as one of the most important chemical discoveries of the year. In addition to copious quantities of oxalic acid and of other products not yet determined, the author obtained an acid to which he has given the name of anthraconic, and which he found to closely resemble mellitic acid in its properties. The experiment was repeated with charcoal purified in a stream of chlorine gas, also by calcining cream of tartar, by the reduction of carbonic acid with phosphorus, and from graphite. All of these varieties of carbon yielded analogous results. So great was the interest manifested in the announcement, that the leading chemists adjourned to the Professor's laboratory, there to repeat the tests and to examine into the nature of the incidental products. They soon came to the conclusion that the new body was identical with mellitic acid. By treating the anthraconic acid with caustic soda, benzol was produced, which was converted into nitrobenzol in the usual manner, and from this product aniline was manufactured.

According to a decree in France, dated March 7, 1808, it has been enjoined that no wells shall be bored or dug out at a less distance than 100 metres in all directions from any burial-ground. Dr. Lefort having found that not only in many country villages, but also in several towns, this regulation has not been observed, has made some experiments on the water of a well at Saint Didier (Département de l'Allier), which locality is situated on an alluvial soil. This water is used for drinking purposes by the parish priest and a portion of the inhabitants, and, on examination, the author found it to contain not only a large proportion of ammoniacal salts, but also, on evaporation, to leave a very large quantity of a dark-coloured organic matter mixed with carbonated salts, which, on being mixed with some hydrochloric acid, gave off an offensive carbonic acid gas, the smell being somewhat akin to a mixture of a concentrated solution of glue and butyric acid. The well is very deep, and the water is quite clear and bright, but exhibits, especially in summer time, a very vapid taste, while, in the warm season of the year it rapidly becomes putrid. The author comes to the conclusion that, in any soil, a well dug at the distance of 100 metres from either burial-grounds or battle-fields is quite useless to protect the water of even deep wells from becoming so contaminated with organic and other injurious matter as to make them very dangerous to health.

A Detroit druggist, assisted by two gentlemen, resolved to make a number of experiments on spontaneous combustion. They first took a piece of cotton cloth, which had once formed part of a sheet, and which had been used until quite threadbare, and smeared it with boiled linseed oil. An old chest was placed in the loft of a store-room back of the drug store, a piece of zinc over it, and another piece under it, and then the chest was filled with paper and rags, and this particular piece of cloth placed in the centre. Although the room was not a light one, and the weather cold, in eight days there was such a smell of fire about the trunk, and the chances were so good for a conflagration within it, that the contents were emptied. An examination showed that the fibre of the oil-cloth had untwisted and shrivelled up, and that the rag looked as if it had been held too near a hot blaze. In April, when the rays of the sun were stronger, a pair of painter's overalls, literally covered with paint and oil, were rolled up, a handful of pine shavings placed inside, and these were crowded in next to the roof boards of the loft. The experiment was not a week old when, during one warm afternoon, a smell of smoke alarmed a workman in the next room, and he found the overalls burning, and so tinder-like was the cloth that it had to be crowded into a pail of water to prevent total destruction. During the hot weather of August, a handful of old cotton rags, in which two matches were placed, but which were not smeared with oil or other matter, were shut up in a tin box, and hung up in the loft, a rear window allowing the afternoon sun to shine directly on the box for several hours. Toward the close of the fourth day the druggist took down the box to see how the experiment was progressing, and found the contents to consist of nothing but a puff of black cinders, which flew all over him as the lid was lifted. Having a vacant corner in his brick wood-house at home, the druggist took the trunk up there, where there was no danger of burning a building. He filled the trunk with the contents of the paper rag-bag, and then smeared one with benzine and threw it in last of all. The trunk was shut tight, everything cleared away from its vicinity, and he commenced watching. One day the family came home to find a few ashes marking the place where the trunk stood, while the bricks above and around were badly stained with smoke.

At the last meeting of the Chemico-Agricultural Society at Belfast, under the presidency of Dr. Knox, late Poor Law Inspector, the subject of whisky adulteration was brought under consideration by Dr. Hodges, who exhibited a specimen of that liquid brought to him by two men who had been physically incapacitated by drinking a small portion of it in a public-house. He found, on analysis, that it contained a large amount of naphtha. He had also discovered that ingredients of even a more deleterious character were used in the process of adulteration,—mixtures containing sulphate of copper (blue-stone), cayenne pepper, sulphuric acid (vitriol), and a little spirits of wine. One specimen submitted to Dr. Hodges by a number of provision cutters and curers, was composed of naphtha and a slight colouring of whisky. The men who had imbibed a small quantity of it were affected with serious symptoms; and this, said Dr. Hodges, was a fair specimen of the drink sold in low-class public-houses. The trade in this noxious compound is carried on with impunity, no local authority in Belfast or in the Province of Ulster caring to exercise the powers with which the legislature has invested them for the suppression of the traffic.

Mr. J. T. King recommends the following process for detecting sulphuric acid in vinegar. It will detect the 500th part of free sulphuric acid, and is accurate for all practical purposes. An ounce of the vinegar to be examined is, by evaporation upon a water-bath, reduced to about half a drachm, or the consistency of a thin extract; when quite cold half a fluid ounce of strong alcohol is thoroughly incorporated; the free sulphuric acid will be taken up by the alcohol, to the exclusion of any sulphates; the alcoholic liquid solution should stand for several hours, and then be filtered; add to the filtrate 1 fluid ounce of pure distilled water, and evaporate off the alcohol by the application of a gentle heat; the remaining liquid is again left standing for several hours, and again filtered; to the filtrate, previously acidulated with a few drops of pure hydrochloric acid, a solution of chloride of barium is added, which, if sulphuric acid be present, will yield a white precipitate.

Dr. Personne accidentally obtained a small piece of a chocolate-brown substance, which originally was apparently a paste, but is now hard. On further examination it was found to consist of a lime-soap, mixed with myrrh, olibanum, benzoin, and probably some essential oil. The author states that at the present day there is sold in Egypt as a perfume a substance of similar composition, and locally known as *Bouh-Kourre-bare*, which means perfume from the Arabian frontier.

M. A. Muntz has instituted, with great care and on a practically large scale, a series of experiments, with the view of ascertaining the quantity of materials consumed by the hop-plant during its growth and development from spring to autumn (hop-picking time), for a number of 6316 plants placed on a hectare (= 2·47 acres). The quantities alluded to, expressed in kilos., are—Water, 11270·270 kilos.; carbon, 2624·361; hydrogen, 315·547; oxygen, 2011·393; nitrogen, 91·141; phosphoric acid, 22·699; magnesia, 24·352; potassa, 41·812; soda, 0·455; non-specifically determined mineral matters, 133·278.

According to G. Salet, when a crystal of iodine is put into a hard glass tube, the tube sealed, and then strongly heated to redness at some distance from the iodine, the latter substance will be seen, after the heating of the tube has been discontinued, to become volatilised, and to exhibit when entering the still hot portion of the tube a brilliant red light. This experiment may be also made by means of a glass tube provided with a spirally-wound platinum wire, which is made red-hot by means of an electric current.

A new product of decomposition of commercial aniline has been found by R. Braun and Ph. Grieff. When a large quantity of commercial aniline is distilled along with lime, the last portion of the distillate is not quite freely soluble in hydrochloric acid; further investigation led to the conclusion that the properties of that substance agree with those of carbazol, as described by Graebe and Glaser. Carbazol is present in crude tar oil, but the authors surmise that this substance might be formed by the drying of the mixture of aniline and lime in contact with the very hot metal of the iron still.

Based upon experiments very successfully made with animals, Drs. Eulenberg and Wohl propose the use of animal charcoal, made up into pills as an efficient antidote against the bad effects of phosphorus in the lucifer match manufactories; they prefer this substance to oil of turpentine, which, though an effectual antidote against phosphorus, causes, in many instances, severe headaches when internally taken.

The magnetic sand, which exists in immense quantities on all sides of Mount Etna, has a sp. gr. of 2·813, and is scarcely acted on by acids. The results of its analysis by J. B. Hannay gave—Silica, 52·71; magnetic oxide of iron, 19·44; alumina, 19·09; lime, 6·61; and magnesia, 1·85.

THE PROGRESS IN SCIENCE AT THE INTERNATIONAL EXHIBITION OF 1872.

ENTERING the South Gallery we are in the department apportioned to recent scientific inventions and new discoveries. This year the department presents no striking feature, so that we must proceed to notice the exhibits as they occur to us. At the entrance of the South Gallery stands the Electric Motor Clock of Messrs. Cooke and Son, of York; this clock, actuated by a not very powerful battery, controls and drives the many clocks required in the Exhibition buildings. The instrument has now stood a very severe test, this being the second year of its working successfully. The construction is exceedingly simple. There are several excellent electric clocks exhibited by Messrs. Moseley and Co., in the French *annexé*, of which we are sorry no description has been given. Continuing, however, our walk through the South Gallery, we pass a bowser, for tightening and holding ropes, exhibited by A. Paget and Co., several hoists and pulley-blocks, by Tangye Brothers and Holman, and by Head, Wrightson, and Co., and arrive before a model of a house, constructed entirely of waterproof paper, and over which a plentiful rain of water is continually flowing. The paper is rendered waterproof by the cupro-ammonium process, now the property of the Waterproof Paper and Corrugated Fibre Company, and can be seen in the roll, single or double. There are also combinations of cotton or linen fabrics with waterproof paper, in slabs, flat or corrugated, of various thicknesses, for roofing or building purposes, waterproof tubing, panels, &c. Cupro-ammonium is stated to be prepared by the immersion of copper scraps in concentrated liquid ammonia. The fluid becomes deep blue in colour, and possesses remarkable solvent and agglutinising properties with regard to paper, linen, silk, and bone. Fibrous material treated with this fluid is rendered waterpoof. It is stated that oxide of copper precipitated and re-dissolved by ammonia does not possess the solvent power of the solution obtained by the immersion of copper-turnings in ammonia. Any paper sent to the company is made waterproof and corrugated at an expenditure of 40 per cent on the original cost. Near to this exhibit are two non-conducting cements for covering boilers and steam-pipes by Messrs. Fox, Head, and Co., and by Messrs. Leroy and Co. Mr. Barlow, F.R.S., exhibits a very clever instrument for calculating the cubical contents of earthwork. Messrs. T. A. Skelton show a Catoptric Street Lamp now in use on Waterloo Bridge, devised to prevent the waste of light from the higher parts of the lamp. The invention consists in arranging strips of silvered glass in such a way that the maximum amount of light is thrown upon the pathway. Messrs. Lynch and Co. exhibit a knobbed blue-glass poison-bottle to prevent the use of poison by mistake in the dark. Captain E. Sawyer contributes three drawings of a pivot-revolving gun-carriage on rails. This year there are exhibited many very useful little inventions, all of which it is impossible that we can enumerate. Among the most prominent is a contrivance for the prevention of guttering in candles, the contribution of the Rev. J. Langton Clarke, a small glass socket fitting on the candle. This socket is studded with small points of coloured glass, forming a very pretty as well as useful ornament. Another of these minor inventions, and one that will be appreciated by artists, is a reservoir palette for flat tints, preventing evaporation, by Messrs. Ackermann. Returning to what must really be the true object of an exhibition of this nature, the development of manufactures, we have a model of a patent Puddling Furnace, by Mr. Danks; a model of a kiln for burning bricks, by Mr. Batchelar; and a cutting and crushing sugar machine from Belgium, contributed by Léon Goffin. Captain W. H. Noble, R.A., contributes some specimens of gunpowder (R.L.G., L.G., pebble, pellet, and prismatic) recently tried by the Committee on Explosives; also a crusher-gauge for directly determining the pressure of fired gunpowder. Messrs. Bessemer have a very complete series of sectional models illustrating the Bessemer principle of constructing Continuous Low Pressure Ordnance. From Sir Joseph Whitworth and Co. there are excellent models of a Six-pounder Breech-loading Rifled Gun and Carriage, made of Sir Joseph Whitworth's patent compressed metal; and models of a breech-loading field-gun and a breech-loading naval gun and carriage. Major W. Palliser, C.B., shows a Service Muzzle-loading 64-pounder Rifled Gun, converted on the Palliser principle from a smooth bore 32-pounder gun, and having fired 2300 rounds. These are in the West Arcade. Returning to the South Gallery we have, completing the list of furnaces and heating apparatus, the Newport Patent Puddling Furnace and Boiler invented by Jones, Howson, Gjers, and J. Head; also a sectional model of Whitwell's Patent Hot-Blast Fire-brick Stove, erected at the moderate cost of £850 to £1000. Near at hand is a model of an admirable Boat Lowering Apparatus invented and exhibited by Mr. E. J. Hill. This apparatus appears to be extremely simple; by a peculiar form of eye it is contrived that should either end of the boat alone touch the water, the eyes are not liberated; should the boat touch the surface of the water in the complete plane, the eyes are immediately disengaged and the boat set free. The direct application of recently discovered scientific principles meets with but slight representation in the present Exhibition. Dr. Siemens, F.R.S., exhibits his Deep Sea Photometer, an apparatus for comparing the intensities of light at different depths of water. This photometer was used on board H.M.S. *Shearwater*, in August, 1871, in the Straits of Gibraltar. Dr. Siemens also contributes an Apparatus for Working Pneumatic Despatch Tubes on the continuous current system, as established for the transmission of postal telegrams between the West Strand and Central Telegraph Stations, together with an exhauster or steam-jet for drawing the air through the tubes. Colonel H. Stuart Wortley exhibits some results of his New Dry Photographic Process, for working, by the use of collodio-bromide of silver, without a silver bath. Passing from the gallery containing the preceding exhibits, the visitor interested in the useful application of science to every day purposes, will pause before the table at which an attendant of Messrs. D. Nicoll and Co. explains the use of a Fire-proof Starch. This starch renders fabrics uninflammable without affecting their colour, strength, or appearance, and requires only ordinary treatment by the laundress; it can be obtained in small quantities at a moderate price.

Science, as represented in its own division, may be said to have now been exhausted by our imaginary visitor; but the ground upon which Science and Art marshal their combined forces is where the several kinds of musical instruments are exhibited. The instrument of general interest, the pianoforte, appears either in the gorgeous case-work of Messrs. Hopkinson and of Messrs. Erard, whose instruments are marvels of marqueterie work, or in the full-toned bijou pianofortes of the former firm, certainly the most powerful of the middle-class instruments, and in this respect not inferior to some of the grands exhibited. The Iron-Bijou-Grand Pianoforte, as well as the Full Concert-Grand contributed by this firm, are worthy of notice in a scientific point of view, from the substitution of iron for wood in those portions of the instrument subject to strain. When we consider that the strings of a seven-octave pianoforte tuned to concert-pitch exert a tension equal to nearly a half-score of tons, the employment of some material occupying less space and of more regular structure than wood is evidently desirable.

The applications of electricity are yearly becoming more numerous, and since its first employment in organ construction by Mr. Barker, of Paris, it has received considerable attention from Messrs. Bryceson Brothers and Co., who built their first electric organ for Her Majesty's Opera in 1868. The organ exhibited in the present Exhibition consists of one manual and eight stops. A voltaic battery, electro-magnets, and attenuated air as a motive power, are the chief agents employed. Each key is connected to a separate electro-magnet in the organ, the armature of which is attached to the lever valve of a pneumatic pallet of peculiar construction. On pressing a key an electric current is completed around its corresponding magnet, and the armature being attracted causes the pallet to open and admit wind to the pipes; immediately the key is released the current ceases, the armature returns, and the pallet is closed. Powerful west gallery organs may thus be played from the east end of the church entirely through a cable of insulated wire an inch in diameter, or attached to additional manuals provided for that purpose at a mechanical organ placed close to the choir. The electric current is supplied from four cells of a single fluid battery, the electrodes of which are automatically withdrawn from the exciting fluid when the wind is out of the organ.

The processes of envelope manufacture are among the most interesting exhibits, chiefly by Messrs. Goodall and Son, and by Messrs. John Dickinson and Co. The process commences at the northern end of the gallery, where the paper, as it arrives in endless rolls from the mill, is fixed to the cutting-machine to be cut into sheets of the required size. The paper has next to be "glazed." This is done by interleaving it sheet by sheet with plates of zinc or brass, and passing it in small quantities between rolls under enormous pressure varying from 20 to 40 tons. Out of this paper the "blanks" of the required size are punched, and then have to be gummed on the "nose," that portion which has to be wetted when fastening the finished envelope, 4000 envelopes being gummed in one hour. The blanks have now to be folded, an operation effected by means of machinery. 300,000 envelopes can be completed weekly.

About three o'clock daily the centre of interest is the Marinoni machine, printing the "Echo" newspaper at 12,000 copies per hour. The printing-press is the consummation of scientific principle, and we regret not being able to afford space for the description of the many admirable inventions. We must, however, record the endeavours of Mr. Walter, M.P., to attain the best form of "perfecting" machine, or one that prints both sides of the sheet at a single operation, in order to dispense with the manual skill required in other machines to lay on sheet after sheet with the requisite accuracy. The Walter press requires but two attendants, and the paper passes continuously through the machine. At one end of the machine is placed a reel of tightly-rolled paper, in the form in which it leaves the paper-mill, nearly four miles in length. The paper is led from the reel into a series of damping cylinders, and thence between the first and second of four cylinders raised perpendicularly above each other. The top cylinder is encircled by the stereotype casts of four pages of type, whilst round the lowest of the four cylinders are the stereotypes of the remaining four pages of the newspaper. The paper is thus printed first on one side and then on the other. Passing to other cylinders, the continuous sheet is cut into lengths, each forming a complete newspaper. 12,000 copies of the complete paper can be printed in one hour. It should be said that it is to Mr. Walter that we owe much of the progress in printing.

We understand upon authority that no "Official Report upon Recent Scientific Inventions and New Discoveries" will be published this year.

QUARTERLY LIST OF PUBLICATIONS RECEIVED FOR REVIEW.

Elements of Chemistry: Theoretical and Practical. By William Allen Miller, M.D., D.C.L., LL.D. Revised by Herbert McLeod, F.C.S. Part I.—Chemical Physics. Fifth Edition. *Longmans and Co.*

Introduction to the Study of Biology. By H. Alleyne Nicholson, M.D., &c. *William Blackwood and Sons.*

On Mankind: their Origin and Destiny. By an M.A. of Balliol College, Oxford. *Longmans and Co.*

Natural Philosophy for General Readers and Young Persons. Translated and Edited from Ganot's "Cours Elémentaire de Physique." By E. Atkinson, Ph.D., F.C.S. *Longmans and Co.*

Essays on Astronomy. By Richard A. Proctor, B.A., Cambridge. *Longmans and Co.*

Geological Survey of Ohio. Report of Progress in 1870. By J. S. Newbury. *Columbus: Nevins and Myers.*

The Earth's Crust. A Handy Outline of Geology. By David Page, LL.D., F.G.S. Sixth Edition. *William Blackwood and Sons.*

A Manual of Chemical Physiology, including its Points of Contact with Pathology. By J. L. W. Thudichum, M.D. *Longmans and Co.*

Man in the Past, Present, and Future. From the German of Dr. L. Büchner. By W. S. Dallas, F.L.S. *London: Asher and Co.*

Conversations on Natural Philosophy. By Mrs. Marcet. Revised and Edited by Francis Marcet, F.R.S. Fourteenth Edition. *Longmans and Co.*

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